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THE ACTION OF POTASH SALTS ON THE ACID SOILS OF ASSAM.

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Introduction.

After studying the distribution of tea mosquito (*Helopeltis theivora*) in the tea districts of North-east India in relation to the soil, Andrews (1) came to the conclusion that the susceptibility of the tea bush to attack might be influenced by the application of potash manures to the soil. Many experiments were carried out in this connection and it was found that potash manuring on light soils lifted the blight whilst on heavier soils such manures had no or only a temporary effect unless applied constantly and in large doses. In a later paper (2) the same worker describes how by cutting certain of the tea bush roots and placing them in solutions of potash salts, the blight lifted after three weeks. Other manures failed to act in this manner. Having thus demonstrated the importance of potash in connection with mosquito blight the next step was to discover why potash added as a manure should not in the case of heavy soils produce permanent results. To allow for the greater fixation of potash by heavy than by light soils, enormous doses of potash manures, which should ensure a distinct increase in the available potash, were applied. The results showed the effect was slightly beneficial but not nearly so marked as might be expected. The question which naturally arose was one concerned with the action of the manure after it had been applied, and it was to solve this problem that the work detailed below was originally taken in hand.

The Acid Soils of the Brahmaputra Valley.

Before the fixation of potash and other bases by the soils of North-east India can be fully appreciated, a brief description of the

district concerned is necessary. The Brahmaputra Valley is a broad alluvial plain, the soil of which is, by European standards, quite poor. The minimum rainfall necessary for successful tea growth is about 60 inches, but in most of the tea districts it is much more and in parts it rises well above 200 inches. This heavy rainfall combined with the ease with which, owing to the general lightness of the soil, water flows away has undoubtedly been the cause of the low lime figure (about 0·01% CaO) met in these soils. The acidity is largely due to the absence of lime and the presence of other inorganic salts. Measured by the Veitch-Albert method it varies from 800 to 2,000 parts lime per million with the lighter soils and rises to 4,000 on parts on the Red Bank Dooars where the clay content often reaches 40%.

The action of potash and ammonium salts on the ordinary soils of Great Britain which are usually well supplied with lime, has been fully studied and it is well known that part of the base added as a manure is fixed and that other bases—calcium, magnesium, manganese and potassium in the case of an ammonium salt being added—are liberated.

With soils poor enough in soluble strong bases to be acid, it is possible for the weaker bases, iron and alumina to enter into the soil solution. Connor (3) points out that the immediate effect of the addition of soluble fertilizer salts of strong acids to this type of soil is to increase the solution of salts of iron and alumina and that these salts are fixed by phosphates. The same writer (4) discusses the formation of acid soils. He states that there is a tendency for all soils to become acid, especially where the rainfall is heavy. The constitution of the aluminium silicates is an important factor in soil acidity which varies with the relative proportion of the combined water in the silicates.

The action of the tea soils of Assam is similar to that of the soils described by Connor so far as the liberation of salts of weak bases on treatment with soluble fertilizer salts of strong acids is concerned. Moreover, it has been noticed that the acidity of the same type of soil varies with the rainfall of the district. Thus

light soils in the Dibrugarh district where the rainfall is 112 inches show acidities varying from 1,000 to 2,500. At Sibsagar, lower down the Valley where the rainfall is 95 inches, the acidities vary from 800 to 2,000. Still lower down at Jorhat where the rainfall is only 80 inches the acidities vary from 500 to 1,500. The variation may well be due to variation in the relative states of hydration of the silicates and of iron and aluminium oxides.

As a rule, the acidity increases with the heaviness of the soil.

It seems that the inorganic acidity displayed by the soils under consideration is one quite distinct from that shown by peat soils and is probably closely related to the adsorptive power of the soil.

The Fixation of Potash by the Acid Soils of Assam.

Most of the published work on the fixation of potash by soils has been done on soils with a sufficient supply of lime. Bearing in mind the fact that base fixation is partly a matter of adsorption and partly one of interchange of bases, the acidity of a soil should not enter into this side of the question. The chief difference between the action of potassium salts of strong acids on acid soils and on chalky soils is that with an acid soil a greater number of bases are capable of liberation than with a calcareous soil.

Six different soils were employed in the work described and below are shown the mechanical analyses as determined by Hall's sedimentation process. The figure which gives the index to the degree of hydration of the clay and hence to the inorganic colloidal content of the soil is the loss on ignition of the clay fraction for it may be supposed that most of the organic particles of the size of clay would have been dissolved out during the process of deflocculation with ammonia.

If the soils are ranged according to the loss on ignition of the clay it is seen that Leesh River, in spite of its lightness, evidently contains more active colloidal matter than the much heavier clay soils of Chalounie and Numaligarh.

TABLE I.

Showing the Mechanical Analyses of Soils employed in Base Fixation Experiments.

——	Loss on ignition.	Coarse sand.	Fine sand.	Silt.	Fine silt.	Clay.	Loss on ignition of clay.
Leesh River ...	6·46	6·45	22·97	20·10	24·10	8·75	4·70
Chalounie ...	7·01	19·55	7·40	20 50	13·84	28·47	4·23
Numaligarh Clay	5·66	10·21	19 04	10·47	18·56	30·50	4·02
„ Loam	4·29	8·93	37 64	21·32	14·81	11·00	2·36
Tocklai Loam ...	2·97	5·29	50·51	11·21	21·22	6·96	2·08
„ Sand ...	3·27	4·59	61·87	12·37	11·02	3·86	1·84
Borbhetta ...	2·22	5·25	64·40	11·66	8·72	4·80	1·40
Gutoonga ...	2·11	6·33	45·21	14·40	19·40	7·00	0 40

The air dried soil which usually contained 2—3 per cent. moisture was used in all experiments. 20 grams soil were shaken with 200 cc. of solution for one hour in the cold and then filtered on a Buchner funnel. The filtrate was analysed. Each experiment was done in duplicate and sometimes in triplicate. In calculating he amount of potash fixed by the soil, the water soluble potash in the original soil has been ignored. In most cases this quantity is of the order 0·003 grams K_2O per cent. except in the case of Leesh River where it is 0·009 grams. Generally the water available potash is a negligible quantity and in cases where its magnitude is comparable with the amount of potash fixed from potassium sulphate solution its consideration would necessitate the assumption that it is the same in the presence of potash solution as in water.

TABLE II.

Showing the Fixation of Potash by Soils from Potassium Sulphate Solutions of Different Strength.

Soil.	ORIGINAL STRENGTH K_2SO_4 = GMS. K_2O PER LITRE.						
	·052.	·103.	·214.	·448.	·605.	·841.	1·190.
Chalounie ...	0·034	0·044	0·046	0 048	0·115	0·136	0·158
Numaligarh Clay	0·027	0·043	0·093	0·158	......	0·143	......
„ Loam	......	......	......	......	0·035	......	0·045
Leesh River ...	0·015	0·017	0·021	0·031	0·035	0·036	0·036
Tocklai Loam ...	0·012	0·014	0·018	0·043	......	0·047	......
Borbhetta ...	......	......	......	......	0·035	0·039	0·045
Gutoonga ...	......	......	......	......	0 020	0·027	0·033

The results are best appreciated from the curve in Fig. I, which shows the relationship between the original and final potash solutions. Chalounie—a clay—acts similarly to that mentioned by Hall (5) and referred to later in Table IV and Fig. II. The sandy soils show the same characteristics as the clay, only in a less marked degree, over a certain range of potash concentrations. The case of Numaligarh clay is inexplicable at present for the fixation follows an exponential curve. Unfortunately further samples of this soil were not available. The Numaligarh loam, from the two fixation values given, appears to be acting as the other light soils.

The slight fixation of potash by Leesh River is, at first sight, surprising. This soil is rich in potash mica and it is possible that most of its inorganic colloidal content consists of potash compounds which would not be expected to readily exchange potash or to react with potash salts.

From the general trend of the curves it appears that the action between the soil and salt solution is a chemical one and follows the law of mass action. Were it simply a case of adsorption, the curve would be an exponential one in accordance with the adsorption formula. This point is discussed more fully below.

The question of the availability of the potash fixed is one of great economic importance. It has been noticed in dealing with mosquito blight in tea by means of potash manures, that on clay soils a single large dose is more effective than several small doses whilst on lighter soils several small doses prove of more use. The ease with which soluble fertilizers are leached from sandy soils explains this. The tables below show the water and citric acid available potash in the soil after it has been treated with potassium sulphate solution.

TABLE III.

Showing the Availability of Potash in Soils after Treatment with Potassium Sulphate solution.

CHALOUNIE SOIL.

Citric acid available potash in original soil=0·008 gms. per 100 gms. soil.
Water " " " " =0·003 " " 100 " "

Strength K_2SO_4 solution gms. K_2O per litre	0·052	0·103	0·214	0·448	0·605	0·841	1·119
K_2O fixed per 100 gms. soil ...	0·034	0·044	0·046	0·048	0·116	0·136	0·158
Citric acid available K_2O after treatment with K_2SO_4	0·047	0·072	0·062	0·101	0·129	0·117	0·122
Water available K_2O after treatment with K_2SO_4 ...	......	......	......	......	0·081	0·076	0·098

Numaligarh Clay.

Citric acid available K_2O in original soil $=0·008$ gms. per 100 gms. soil.
Water " " " " $=0·0014$ " " 100 " "

Strength K_2SO_4 solution gms. K_2O per litre	0·052	0·103	0·214	0·448	0·841
K_2O fixed per 100 gms. soil ...	0·027	0·043	0·093	0·158	0·143
Citric acid available K_2O after treatment with K_2SO_4	0·043	0·038	0·041	0·041	0·148
Water available K_2O after treatment with K_2SO_4 ...	......	......	......	......	0·080

Leesh River Soil.

Citric acid available K_2O in original soil $=0·024$ gms. per 100 gms. soil.
Water " " " " $=0·009$ " " 100 " "

Strength K_2SO_2 solution gms. K_2O per litre	0·052	0·103	0·214	0·448	0·605	0·841	1·190
K_2O fixed per 100 gms. soil ...	0·015	0·017	0·021	0·031	0·035	0·036	0·036
Citric acid available K_2O after treatment with K_2SO_4	0·030	0·033	0·038	0·057	......	0·070	0·109
Water available K_2O after treatment with K_2SO_4 ...	......	......	......	......	0·042	0·033	0·042

TOCKLAI LOAM.

Citric acid available K_2O in original soil=0·007 gms. per 100 gms. soil.
Water " " " " =0·003 " " 100 " "

Strength K_2SO_4 solution gms. K_2O per litre	0·052	0·103	0·214	0·448	0·841
K_2O fixed per 100 gms. soil ...	0·012	0·014	0·018	0·043	0·047
Citric acid available K_2O after treatment with K_2SO_4	0·018	0·024	0·028	0·058	0·065
Water available K_2O after treatment with K_2SO_4 ...	......	......	......	......	0·044

The figures are very irregular and it is difficult to understand why the citric acid available potash is in many cases greater than the amount fixed plus the available potash in the original soil. A possible explanation is that during the interchange of bases effected by the potassium sulphate many of the loose potash combinations are disturbed and rendered soluble in citric acid.

Before leaving the question of the nature of base fixation by soils it will be of interest to refer again to the case of amonia fixation from anonium chloride mentioned by Hall (5). The figures are given below :—

TABLE IV.

Showing the Fixation of Ammonia from 3 litres of Ammonium Choloride of Different Strengths by 100 grammes of Pure Clay (Hall "Soil," p. 215.)

Original concentration of solution	Original strength NH_4Cl.—gms. NH_3 per 3 litres.	Final strength NH_4Cl.—gms. NH_3 per 3 litres.	Gms. NH_3 absorbed. by 100 gms. clay.	Percentage Ammonia fixed.
N/10	0·51	0·38	0·13	24·7
N/12	0·43	0·32	0·11	28·1
N/15	0·34	0·24	0·10	30·5
N/20	0·26	0·17	0·09	35·3
N/30	0·17	0·10	0·07	40·3
N/50	0·10	0·05	0·05	48·0
N/100	0·05	0·02	0·03	60·0

These results may be plotted either as the percentage of the ammonia withdrawn against original normality from the first and fifth columns or as original against final strength of solution from the second and third columns as is shown in Fig. II. It seems at first that the removal of ammonia from solution follows the law of mass action suggesting that the action is wholly chemical. If the curve is produced, it meets the base line not at the origin but at a point which suggests that at a certain strength of ammonium chloride all the ammonia in solution is removed by the soil. This is not a fact and it must be concluded that with very weak solutions the adsorptive as opposed to the chemical power of the soil to remove bases from solutions, becomes the predominant factor. The exponential from of the curve is again demonstrated with the stronger solutions for after the strength N/30 is passed the rate of removal of ammonia again decreases.

The fixation of ammonia was studied in the case of some of the acid soils of Assam. The method employed was to treat the ammonium chloride extract with an excess of caustic soda and to distil off the ammonia into standard acid. More direct method were found to be inaccurate.

TABLE V.

Showing the Fixation of Ammonia from Ammonium Chloride of Different Strengths by Soils.

Soil.	AMMONIA FIXED BY 100 GMS. SOIL.		
	$NH_3 = \frac{N}{17}$ approx. 0·214 gms. p. l.	$NH_3 = \frac{N}{8}$ approx. 0·437 gms. p. l.	$NH_3 = \frac{N}{4}$ approx. 0·82 gms. p. l.
Chalounie ...	0·039 gms.	0·068 gms.	0·095 gms.
Numaligarh Loam ...	0·022 „	0·061 „	0·084 „
Leesh River ...	0·024 „	0·056 „	0·106 „
Borbhetta ...	0·017 „	0·041 „	0·084 „
Tocklai Sand ...	0·022 „	0·058 „	0·129 „
Gutoonga ...	0·020 „	0,054 „	0·118 „

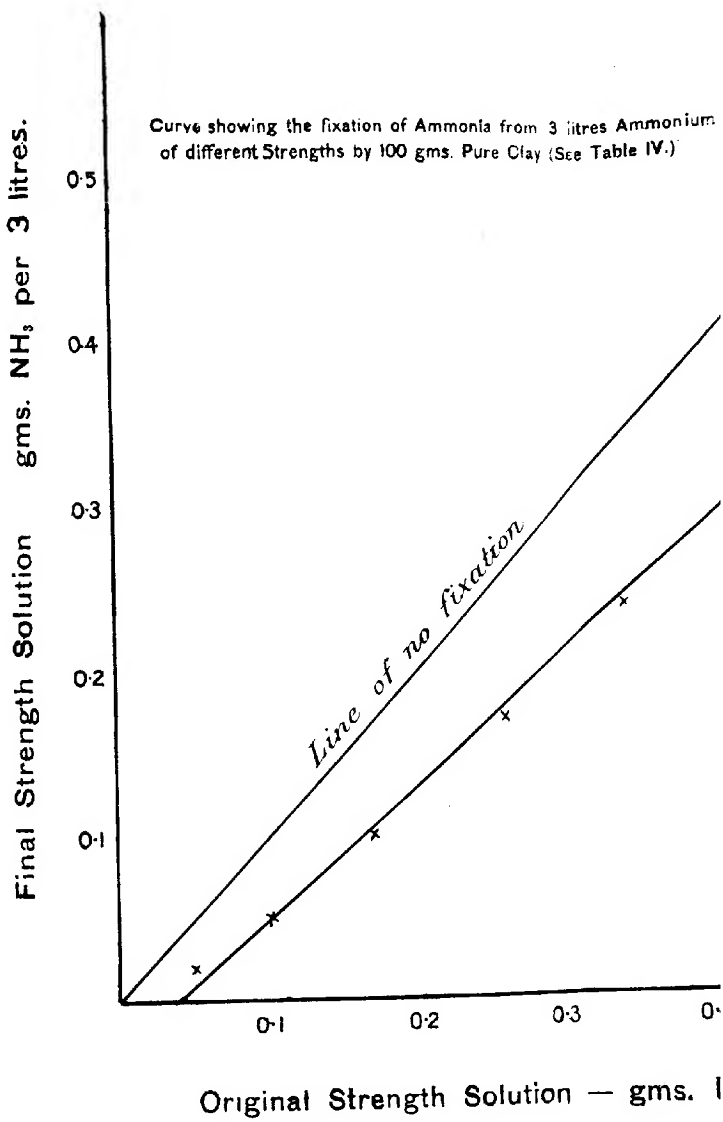
Curve showing the fixation of Ammonia from 3 litres Ammonium
of different Strengths by 100 gms. Pure Clay (See Table IV.)
Final Strength Solution gms. NH_3 per 3 litres.
0·5
0·4
0·3
0·2
0·1
Line of no fixation
0·1
0·2
0·3
0·
Original Strength Solution — gms. I

Fig II

The figures roughly follow those mentioned above. The four sandy soils adsorb a fairly constant ratio of the base added but the heavier soils, like the clay first considered, apparently lose some of that power when the strength of ammonia increases and the fixation curve tends to assume an exponential form. Kelley and Cummins (6) and others state that the reactions between neutral salts and soils are dependent on the concentration and apparently obey the principle of mass action. This does not wholly agree with the present experience.

Manurial Experiments with Potash, Superphosphate and Lime.

In continuation of the study of the effect of potash on crops in the acid soils of Assam several experiments in the field were carried out by Hope (7) and continued by Andrews (8). It had been previously noticed that soils within a comparatively restricted area may act differently with regard to the same type of phosphatic manure and it was decided to observe whether this difference extended to other forms of manuring.

In Jorhat four localities were considered—Borbhetta, Baisahabi, Gutoonga and Sangsua. The fifth district—Leesh River—is situated in the Dooars. Three of these soils were examined in the laboratory. Borbhetta and Gutoonga like the other Jorhat soils are sandy loams very similar both physically and chemically as far as ordinary analyses show. Leesh River soil is characterised by a greater quantity of fine silt than the other two and it is richer in plant food.

The crop grown was a six weeks one, Cowpeas (*Vigna catiang*). Temperatures were about the same during the experiment in all three places, but at Leesh River about double the rain fell to what was registered in the other places. The following are the effects of the different manure :—

Lime.—In only two cases was lime applied alone. At Gutoonga the effect was negligible while at Borbhetta it was one of depression although in the two years following the Borbhetta limed plots went far ahead of the check plots.

To limed, and all other plots, lime at the rate of 800lbs. per acre was added.

Sulphate of Ammonia.—This manure was added to all plots except where potash nitrate was added, at the rate of 150 lbs. per acre, about three weeks after liming. The general effect seems to have been one of depression.

Potash Manures.—Potash was added both as nitrate and sulphate and in small doses of about 50 lbs. and in large doses of 2,500 lbs. and 8,200. lbs. respectively. The effect of the small dose was not marked but on the whole a small increase was observed. The effect of the large dose was one of distinct depression except in the case of Gutoonga where a great rise in crop occurred.

Phosphatic Manures.—Where potash failed, phosphates succeeded far in the excess of what might be expected At Gutoonga the results were negligible. Superphosphate was added in two doses one of 150 lbs. per acre and another of 8,200 lbs. per acre, but the result were about the same in both cases.

Residual Effect.—At Borbhetta the plots were again planted in 1919 and 1920 and the results showed a slakening off in the beneficial effect of superphosphate and increasing benefit derived from potash manures and a lesser increase from lime. Roughly the crops appear to be falling into line with those of Gutoonga three years previously. The experiments were not continued in the other districts, which is much to be regretted.

These differences are undoubtedly due to differences in the chemical action of the soils.

Acid Soils and Toxic Alumina.

At this point it is convenient to take up again the discussion of acid soils from the theoretical point of view.

It seems probable that inorganic soil acidity is a potential acidity. Certain colloidal bodies if they are highly hydrated act as acids towards bases and as a result iron and aluminium salts pass into the soil solution. Rice (9) shows that on shaking acid soils with potassium nitrate solution aluminium but never iron passes into solution. The conclusion is drawn that the presence of loose combinations of weaker bases such as alumina, is the true cause of infertility of acid soils and not the presence of hydrogen ion.

In some soil solutions alumina may be present before the addition of manures. In this connection it is interesting to note that Warth and Po Shin (10) state that with the paddy soils of Burma, which are usually acid or neutral, the higher the percentage of soluble silica, the more phosphate is required in the soil to give a good crop. Now the soluble silica is a factor of the potential colloidal content of the soil and hence of the chemically active fraction. In the absence of an alkaline soil solution there will undoubtedly be a certain amount of colloidal hydrated iron and alumina present. The action of phospates would be to render these substances insoluble.

Two sets of factors, the physical and chemical constitution of the soil, affect crop adaptation and growth. The latter condition is to an enormous extent influenced by the former. A case in point is the instance of two contiguous plots under tea in the Surma Valley, one of which was badly attacked by tea mosquito whilst the other was quite free. A difference between the soils exists which cannot be shown by ordinary analyses given below :—

TABLE VI.

Mechanical Analyses.

	Unblighted area.	Blighted area.
Moisture in sample as received ...	22·18 per cent.	22·22 per cent.
Moisture in air dried sample ...	2·98 "	3·64 "
Soluble in dilute acid	0·97 "	0·79 "
Coarse sand	11·95 "	14·92 "
Fine sand	44·87 "	36·77 "
Silt	12·48 "	13·79 "
Fine silt	14·71 "	15·82 "
Clay	6·13 "	8·80 "
Loss on ignition	5·24 "	5·02 "

Chemical Analyses.

———	Unblighted area.	Blighted area.
Acidity*	2027	2235
Total Nitrogen	0·175 per cent.	0·166 per cent.
Available Potash	0·147 ,,	0·172 ,,
Available phosphate	0·025 ,,	0·022 ,,

* Determined by Veitch-Albert method, expressed as parts lime per million.

The blighted plot had been over cultivated for years and was a puddled, sticky mass. The soil of the other plot was a friable loam although, at the time of sampling, both soils contained the same moisture.

It seems possible that the above may be an example of alumina becoming sufficiently hydrated to assume a colloidal state and hence to become a factor in the soil solution. Probably with ideal drainage such a thing would not be possible. Kobayashi (11) working on Japanese acid soils, came to the conclusion that the compound $Al_2O_3\ SiO_2\ x\ H_2O$ is acid by virtue of its adsorptive power only when x becomes greater than 6. Without accepting any such definite degree of hydration or the necessity of the combination with silica, it seems highly possible that some definite state must exist when alumina takes on such a property as is stated above.

In order to determine whether alumina is toxic to tea, seedlings were treated with aluminium sulphate. The seedlings under consideration received an ideal manure analysing to

Nitrogen as nitrate	...	= 8·7 parts per million.
Water available K_2O	...	= 0·0012 per cent.
,, ,, P_2O_5	...	= 0·00074 ,,
,, ,, MgO.	...	= 0·00024 ,,

and in addition aluminium sulphate equivalent to 0·0001 per cent. Al_2O_3. After five weeks the toxic effect became apparent. The shoots on the plants receiving alumina became dormant and lost their turgidity. At the end of four months the treated seedlings died while the check plants were still vigorous.

Assuming then that the Assam acid soils are capable, under certain conditions of hydration, of giving solutions containing toxic alumina, the explanation of the manurial experiments described on page 51 follows naturally. The action of superphosphate on Assam soils has been fully studied by Meggit (12) and his statements are bourne out by the results obtained at Borbhetta and by the experience gained on many tea gardens in the Jorhat district. The great benefit is due to the precipitation of alumina chiefly and probably iron in a lesser degree. The action of lime is due to the precipitation of alumina as the oxide or as calcium aluminate. The preliminary depression often experienced with the application of lime, especially on heavy soils, may be due to the solution of small quantities of alumina in some form or other. Mirasol (13) has shown that aluminium oxide and phosphate have no toxic action on plants while it was further found that on washing a soil with a solution of potassium nitrate or sulphate, the acidity was removed and also 59 per cent. of its aluminium. The period during which leaching takes place is apparently the period of crop depression experienced soon after the application of potash manures.

THE ACTION OF SUPERPHOSPHATE ON THE ACID SOILS OF ASSAM.

In order to follow fully the action of potash manures on Assam soils together with the liberation of alumina some consideration of the action of superphosphate is helpful.

Soils were shaken for one hour in the cold with superphosphate solutions of different strengths. Pratolongo (14) has shown that the action between phosphates and soils which are poor in lime is practically instantaneous so that prolonged shaking is unnecessary. The soil after treatment with superphosphate was washed free from phosphates and then treated with potassium sulphate solution.

The reaction with superphosphate is a highly complicated one. First there is the fixation of iron, alumina and, to a small extent calcium, as insoluble phosphates. The action of the calcium sulphate in the manure is probably similar to that of potassium sulphate. A third reaction will result from the free sulphuric acid present in superphosphate. The result of these three reactions

which are primarily independent and ultimately inter-dependent is shown in Table VII below :—

TABLE VII.

Showing the Fixation of Phosphate (P_2O_5) from Superphosphate Solution by 100 grams. soil.

Soil.	P_2O_5 = 0·193 gms. per litre.	P_2O_5 = 0·378 gms. per litre.	P_2O_5 = 0·730 gms. per litre.	P_2O_5 = 1·400 gms. per litre.
Chalounie ...	0·16 gms.	0·26 gms.	0·33 gms.	0·528 gms.
Numaligarh Clay...	0·16 "	0·17 "	0·23 "	0·285 "
Leesh River ...	0·07 "	0 13 "	0·12 "	0 262 "
Tocklai Loam ...	0·04 "	0·08 "	0·10 "	0·166 "
Borbhetta ...	0·04 "	0·07 "	0·07 "	0 086 "
Gutoonga ...	0·03 "	0 06 "	0·07 "	0·183 "

With the lighter soils there appears to be a slowing up in the rate of fixation between superphosphate solutions of strength 0·378 and 0·730 gms. P_2O_5 per litre, after which the rate again increases. This stage appears to have been reached earlier with Numaligarh Clay and is not experienced at all with Chalounie for the particular strengths of solutions used.

The fixation of potash following in the action of superphosphate is shown below :—

TABLE VIII.

Showing the Fixation of Potash from Potassium Sulphate Solution of Strength K_2O=0·214 grams per litre after preliminary treatment with Superphosphate solution of varying strengths.

Soil.	Per 100 grams soil.	K_2O fixed by original soil.	Strength superphosphate as grams P_2O_5 per litre 0·193	0·378	0·730	1·400
Chalounie ...	Gms. P_2O_5 fixed		0·16	0·26	0·33	0·53
	" K_2O "	0·047	0·068	0·064	0·107	0·055
Numaligarh Clay	Gms. P_2O_5 fixed		0·16	0·17	0 23	0·29
	" K_2O "	0·098	0·065	0·081	0·100	0·048
Leesh River ...	Gms. P_2O_5 fixed		0·07	0·13	0·12	0·26
	" K_2O "	0·030	0·039	0·071	0·084	0·025
Tocklai Loam ..	Gms. P_2O_5 fixed		0 04	0·08	0·10	0·17
	" K_2O "	0·021	0·044	0·069	0·090	0·044
Borbhetta ...	Gms. P_2O_5 fixed		0·04	0·07	0·07	0·09
	" K_2O "	0·27	0·034	0·063	0·086	0·021
Gutoonga ...	Gms. P_2O_5 fixed		0·03	0·06	0·07	0·10
	" K_2O "	0·17	0·034	0·066	0·082	0·025

The figures in the first column show the fixation by the untreated soil and it is at once apparent that the whole soil action is changed and the chemical activity increased for the fixation of potash subsequent to superphosphate treatment bears no relationship to the original figure. With the rise shown in phosphate fixation with a solution of strength 1·400% P_2O_5 a big drop in the amount of potash fixed occurs and the capacity of the soil in this direction approximates to that of the original, untreated soil.

With the fixation of potash following on superphosphate treatment the bases iron and alumina are still liberated. Much more work is necessary before the above reactions can be explained.

THE LIBERATION OF BASES FROM ACID SOILS.

The action of salts on alkaline soils takes place in three distinct directions, on the zeolites and, as Sullivan (15) has shown, on certain silicates, on the humus and on the calcium carbonate. With the zeolites a double decomposition takes place with the liberation of calcium, magnesium and potassium. From the humus and calcium carbonate, lime is also brought into solution. With the acid soils of Assam this action is modified for the solution of weaker bases iron and alumina is made possible. Now if the action is simply one of double decomposition, the bases liberated should be equivalent to the amount of bases fixed. This point was investigated and the results are shown below in Table IX.

The calculations for converting liberated iron and alumina to potash equivalent were based on the following :—

$$3\ K_2O : 2\ Al_2O_3 : 2\ Fe_2O_3 = 283 : 204 : 318.$$

In all cases except Numaligarh where no iron is liberated and Chalounie where mostly iron is liberated the ratio for converting iron and alumina to potash is taken as 6/7 which assumes that the greater portion of the liberated base is alumina. With Numaligarh the ratio 5/7 was taken and with Chalounie 7/7.

In dealing with the unmixed bases lime and magnesia the actual equivalent weights were taken.

The magnesia residues were too small to weigh. The Chalounie magnesia precipitate was the largest, Borbhetta the next, Gutoonga the smallest.

TABLE IX.

Showing the Liberation of Bases by Soils on Treatment with Potassium Sulphate of Strength $K_2O = 0{\cdot}841$ gms. per litre together with the Potash Equivalents of the Liberated Bases.

Soil.	Gms. K_2O fixed per 100 gms. soil.	Gms. $\left.\begin{matrix}Al_2O_3\\Fe_2O_3\end{matrix}\right\} = K_2O$.	Gms. $CaO = K_2O$.	Gms. Mgo.	Total bases as Gms. K_2O.	Remarks.
Chalounie ...	0·136	0·0163=·016	0·012=0·020	trace	·036	mostly Fe_2O_3
Numaligarh Clay ...	0·143	0·0153=·011	0·014=0·023	,,	·034	No. Fe_2O_3
Leesh River ...	0·036	0·0063=·005	0·011=0·018	,,	·023	
Tocklai Loam...	0·047	0·0103=·009	0·022=0·037	,,	·046	
Borbhetta ...	0·039	0·0153=·013	0·008=0·013	,,	·026	
Gutoonga ...	0·027	0·0103=·009	0·012=0·020	,,	·029	

It will be noticed that with the four sandy soils—Leesh River, Tocklai, Borbhetta and Gutoonga—the fixed potash is almost wholly accounted for by the liberated bases. The clay soils show a distinct discrepancy and have been shown to fix not only the base but the acid part of the potassium sulphate. The results and calculations following on this are shown below.

TABLE X.

Showing the Fixation of Sulphate Ion from a Solution of Potassium Sulphate, $K_2O = 0{\cdot}841$ grams per litre by Clay Soils.

Soil.	Gms. K_2O fixed by 100 gms. soils.	K_2O EQUIVALENTS. Bases liberated.	K_2O EQUIVALENTS. SO_3 fixed	Total.
Chalounie ...	0·136	0·036 gms.	0·11 gms.	0.146 gms.
Numaligrah Clay...	0·143	0 034 ,,	0·09 ,,	0.124 ,,

The lighter soils fix no sulphateion which can be estimated but the fixation of an acid ion is probably shown in a lesser degree by these soils.

It has also been shown that Chalounie soil fixes sulphate ion from ammonium sulphate but sandy soils do not so far as ordinary analyses show. None of the soils fix the chlorine ion from ammonium chloride. Chalounie fixes a trace of chlorine from potassium chloride (from a solution $KCl = 0 \cdot 0596\%$ Cl., chlorine equivalent to $0 \cdot 0014\%$ is fixed.)

It will be noticed that in every case except Numaligarh, iron as well as alumina is liberated which observation does not agree with the experience of Rice (9) quoted above.

Having shown that alumina is liberted by potassium sulphate from the acid soils of Assam, an attempt was made to explain why Gutoonga soil responded to potash manures while Borbhetta did not until after some time during which a depressing effect was experienced.

Below is a table showing the fixation of potash from potassium sulphate together which bases liberated. A table is also given showing the fixation of ammonium from ammonium sulphate which although it does not enter directly into the discussion is helpful from the point of view of the general theory of the chemical action of the soil.

TABLE XI.

Showing the Fixation of Potash and Ammonium from Salts together with Liberation of bases and Acidity developed.

Figures give grams fixed by 100 grams soil.

$K_2SO_4 = 1 \cdot 200$ grams K_2O per litre.

Soil.	K_2O fixed Gms.	Acidity of Extract*	SiO_2 Gms.	Al_2O_3	Fe_2O_3	CaO	MgO	Bases fixed K_2O equiv.
Numaligarh Loam ...	0·060	212	·0038	·0084	trace	·0202	·0070	·058
Leesh River ...	0·036	99	·0028	·0019	,,	·0178	·0070	·048
Gutoonga ...	0·034	203	·0027	·0080	,,	·0139	·0051	·042
Borbhetta ...	0·044	227	·0026	·0090	,,	·0058	·0091	·039

* as parts lime (CaO) per million parts soil.

$(NH_4)_2\ SO_4 = 1{\cdot}278$ gms. NH_3 per litre.

Soil.	$(NH_4)_2O$ fixed gms.	SiO_2 gms.	Al_2O_3 gms.	Fe_2O_3 gms	CaO. gms	MgO. gms.	K_2O gms.	Bases fixed K_2O equiv.
Numaligarh Loam ...	·044	·0056	·0155	trace	·0188	·0033	·0057	·035
Leesh River ...	·048	·0040	·0040	,,	·0199	·0038	·0041	·027
Gutoonga ...	·024	·0050	·0134	,,	·0129	·0018	·0039	·026

From the first column it will be seen that the nature of the base has a great effect on the amount of base fixed. The low potash fixation by Leesh River has previously been commented on. The ammonia fixation is probably a better criterion of the chemical activity of this soil. The acidities given in the first Table follow fairly well the amount of alumina liberated. The silica rendered soluble is small in all cases.

The most interesting column is that showing the alumina liberations. Had the alumina liberated by Borbhetta soil been much greater than that liberated by Gutoonga then the explanation of the field results would have followed naturally. The chief difference occurs in the amount of lime liberated. The exact significance of this is not clear.

Borbhetta soil liberates a greater quantity of magnesia than the other in accordance with its high magnesia content.

The equivalent of bases liberated in terms of the base fixed agrees roughly except in the case of Leesh River, when Potassium sulphate is considered. With amonium sulphate it must be remembered that a solution about three times the equivalent strength of the potash solution is employed so that the adsorption of the acid radicle may be a considerable factor although this was not estimated.

In Table XII below are shown the bases liberated from the three soils Numaligarh, Leesh River and Gutoonga together with values from some of the Borbhetta plots. In the last column are given acidities as determined by the Veitch-Albert method.

Borbhetta magnesia plot received 800 lbs. magnesia per acre and the Lime Plot 800 lbs. lime per acre. The superphosphate plot received 8,200 lbs. and the potash 8,500 lbs. sulphate per acre. An interval of 3 years has elapsed since the manures were applied and, as mentioned on page 52, the crops are now falling into line with those obtained at Gutoonga three years previously immediately after the application of manure.

TABLE XII.

Showing the Fixation of Potash from Potassium sulphate and and liberation of Bases by Borbhetta Soils.

$K_2SO_4 = 1·200$ grams K_2O per litre.

100 grams soil.

Soil.	K_2O fixed gms	Acidity of Extract*	SiO_2 gms.	Fe_2O_3 Al_2O_3 gms.	CaO gms.	MgO gms	Soil Acidity	Bases liberated as equivalent K_2O gms.
Num. Loam ...	0·060	212	·0038	·0084	·0202	.0070	1314	0·058
Leesh River ...	0·036	99	·0028	·0019	·0178	·0067	1490	0·048
Gutoonga ...	0·034	203	·0027	·0081	·0139	·0053	560	0·042
Borbhetta ...	0·044	227	·0026	·0096	·0058	·0093	1042	0·039
Bor. Magnesia Plot ...	0·112	155	·0025	·0050	·0061	·0047	1198	0·026
Bor. Lime Plot	0·062	56	·0055	·0093	·0355	0047	1064	0·079
Bor. Super. Plot	0·070	114	·0187	·0158	·0585	·0046	1176	0·092
Bor. Potash Plot	0·055	72	·0046	·0122	·0270	·0048	1014	0·067

* as parts lime (CaO) per million parts soil.

The first four soils in the table are untreated soils whilst the second four have had drastic applications of manures which do not yet seem to have reached a state of equilibrium in the soil solution. The amount of potash fixed bears practically no relationship to the bases liberated or to the quantities of iron and alumina set free.

The capability to liberate alumina seems to be no indication of soil fertility when it is remembered that the superphosphate

is giving a 260 per cent. increase on the check plot and that the potash plots have almost attained equal fertility. It will be noticed that although on the superphosphate plot the amount of alumina liberated is increased by 50 per cent., the lime liberated has increased by 700 per cent.

From all four Borbhetta treated plots the same amount of magnesia is liberated and is about half the quantity liberated from the check plot. Further investigation is needed before these facts can be interpreted.

The acidities of the Borbhetta plots were estimated by the Veitch-Ablert method and are not seen to vary much with manuring. The acidity of Gutoonga is about half that of Borbhetta. This low value corresponds with the small loss on ignition of the clay fraction shown in Table I.

All the evidence except that in the last table points to alumina and perhaps iron as the cause of the toxic effect of potash salts on Assam soils. Although it has been shown that aluminium existing in the soil solution as the sulphate giving rise to aluminium ion is toxic, it does not follow that this element in all its forms is toxic to plant. The alumina liberated from the fertile Borbhetta plots in conjunction with lime may exist in a non-toxic state or it may be rendered harmless by the presence of lime.

Many of the results obtained differ from those of other workers. These discrepancies are due no doubt to inherent differences in the soils under consideration.

Conclusions.

1. The acid soils of Assam fix potash and ammonium from their salts in a manner similar to that shown by the chalky soils of Great Britain.

The reaction is partly one of physical adsorption and partly one of chemical interchange of bases.

2. As the clay content of a soil increases the capability of the soil to interchange bases increases. With weak salt solutions

(comparable in strength with those met in the soil) and for strong solutions the predominating factor is physical adsorption.

3. The bases iron and alumina in addition to lime, magnesia and potash are liberated by soluble salts of strong acids from soils poor in lime or alkalies.

4. With sandy soils the bases liberated correspond with the equivalent bases fixed. With heavy soils this is not the case for the salt as a whole appears to be adsorbed.

5. Soluble alumina is toxic to the tea plant.

6. The liberation of alumina by salts from soils does not in itself signify that the soil is infertile. The presence of lime in the soil solution appears to render alumina harmless.

7. Toxic alumina is removed from the soil by the addition of superphosphate which precipitates the insoluble salt, by lime which renders the oxide insoluble or by potash which brings the alumina into solution as a salt which can easily be leached out of the soil.

8. Superphosphate increases the chemical activity of the soils of Assam in that their capability of fix bases is increased.

9. Until the exact significance of soil acidity, as met in Assam, is defined a solution to the problem on hand will not be found. Drainage, soil aeration and tilth are factors capable of so affecting the degree of hydration of certain soil constituents as to render them toxic or non-toxic.

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A NOTE ON THE SUSCEPTIBILITY OF WOODS TO BORER ATTACK, AND ON THE VALUE OF ROSIN VARNISH AS A PROTECTION.

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During the war, when, owing to shortage of freight, large quantities of packed tea had to be stored for extended periods, a considerable amount of damage and inconvenience was caused by the depredations of borers of one kind and another, which obtained entrance into the wood of the chests in the store godowns and elsewhere. The damage, which was most noticeable in the case of country boxes made of Simul, was not by any means unknown previously, but under normal conditions the majority of chests reached the blenders in serviceable condition, whereas delays in transit consequent upon the state of war caused many boxes to become unserviceable long before they could even be shipped from India.

At that time this department made the suggestion that if tea boxes were treated with a rosin varnish a sufficient protection might be afforded to enable the chests to reach Europe in a serviceable condition, and with a view to testing the value of the suggestion simul wood, the most susceptible wood of all, was treated with the varnish and exposed to the action of boring beetles.

The treated wood formed part of a collection of shooks of various kinds of wood kept in the laboratory for reference purposes, and on examining the treated wood on April 29th, 1921 an examination of all the other woods was made at the same time. These woods showed differences in degree of susceptibility to attack sufficiently considerable to be of some interest, and the results of the examination, and of the rosin varnish treatment, are now placed on record. These notes have particular reference to the common "Shot borers*," small beetles belonging to the

* Not to be confused with "Shot-hole borer," which is a different beetle, *Xyleborus fornicatus*, belonging to the family *Ipidae*.

family *Bostrychidae*, which were responsible for most of the damage done to the shooks. The amount of damage done to the shooks was compared by making a count of the number of emergence holes of the beetles.

A marked feature of the attack was that in nearly all cases the centres of the shooks were untouched while the periphery was attacked, though in a few cases one half of the shook was attacked, while the other half was sound, or practically so. This was seen to be due to the difference in degree of susceptibility to attack between heartwood and sapwood. The majority of the shooks were tangential sections of the tree, so that the centre had originally been situated nearer the heart of the trunk, and the borers consequently first attacked the periphery. In a few cases the shook was half of a tangential section, with heartwood at one edge and sapwood at the other, and then the one half was attacked while the other half was left.

Another point shown by the observations is that, speaking generally, harder and darker woods are less attacked than softer and lighter woods, though certain light-coloured soft woods, more particularly wood from Coniferous trees, appear to be resistant. While however it can be said that, although the softer woods are more liable to attack, some are not attacked, the harder woods, of those examined at any rate, appear to be universally resistant to attack by these particular borers.

The woods which were examined, with details of the damage done, are given below, listed under the natural orders to which the trees belong. One side of each shook was planed, the other unplaned. As the shooks were situated, the planed surface of each was exposed to the light, while the unplaned surface was in the shade. The figures show no particular difference between the number of emergence holes on the two surfaces.

MAGNOLIACEAE.

Magnoli campbellii Hook. f. & Thoms.

Vernacular names : Lalchamp (Nep.)

Damage : None.

Michelia cathcartii Hook. f. & Thoms.

Vernacular names : Kalchamp (Nep.)
Damage : None.

Michelia excelsa Blume.

Vernacular names : Bonchampa (Ass.)
Damage : None.

ANONACEAE.

Alphonsea ventricosa Hook. f. & Thoms.

Vernacular names : ?
Damage : None.

CAPPARIDACEAE.

Crataeva religiosa Forst.

Vernacular name : Boron (Ass.)
Damage : None.

MALVACEAE.

Bombax malabaricum D. C.

Vernacular names : Simul (Beng.), Himolu (Ass.)

Damage :	Planed surface	512	holes.
	Unplaned „	485	„
	Edge nearest heart of trunk...	18	„
	„ „ outside of trunk	152	„
	Top end	25	„
	Bottom end	19	„
	Total ...	1,211	holes.

Of the woods examined this is far and away the most susceptible to attack by borers. Although the shook was treated with rosin varnish and, as we believe, thereby rendered immune from attack for two years, it is far more badly attacked than any of the others. The figures show distinctly that wood taken from the outside of the trunk is more subject to attack.

STERCULIACEAE.

Sterculia alata Roxb.

Vernacular names : ?

Damage : None.

Sterculia villosa Roxb.

Vernacular names : Udel, Udar (Hind.)
Udal, Odal (Ass.)

Damage :	Planed surface ...	...	15 holes.
	Edge nearest outside of trunk		15 ,,
	Unplaned surface	...	3 ,,
	Total	...	33 holes.

This wood was very light and spongy, and full of dry rot.

TILIACEAE.

Elaeocarpus lanceaefolius Roxb.

Vernacular names : Bhadras (Nep.)
Belphoi (Ass.)

Damage : No damage done by Bostrychids, but the shook had been bored by a Cerambycid.

Echinocarpus dasycarpus Benth.

Vernacular names : Gobria (Nep.)
Sitarjat (Ass.)

Damage : Six holes on the planed surface.

This shook was exceedingly dry, and had been very badly eaten at one edge by termites. This may have been merely on account of its having been in a corner, adjacent to a batten attacked by termites.

BURSERACEAE.

Garuga pinnata Roxb.

Vernacular names: Dabdabi (Nep.)
Pani-amora (Ass.)

Damage:	Planed surface ...	...	105 holes.
	Unplaned surface	...	84 ,,
	Edge nearest heart of trunk ...		1 ,,
	,, ,, outside of trunk		118 ,,
	Top end ...	...	2 ,,
	Total	...	310 holes.

Canarium bengalense Roxb.

Vernacular names: Nerebi (Ass.)

Damage:	Planed surface ...	...	3 holes.
	Unplaned surface	...	13 ,,
	Edge nearest heart of trunk ...		1 ,,
	,, ,, outside of trunk		22 ,,
	Total	...	39 holes.

All the holes were on the softer edge of the shook, which had warped and split.

MELIACEAE.

Cedrela toona Roxb.

Vernacular names: Tun, tuni (Nep.)
Pooma (Ass.)

Damage:	Planed surface ...	...	7 holes.
	Unplaned surface	...	3 ,,
	Edge nearest outside of trunk		51 ,,
	Total	...	61 holes.

The damaged edge was very soft, especially at one end, which was crumbling away.

Amoora rohituka W. & A.

Vernacular names : Bandriphal (Nep.)
Pitaraj, Tiktaraj (Beng.)
Pitraj (Ass.)

Damage : None.

ACERACEAE

Acer campbellii Hook. f. & Thoms.

Vernacular names : Kabashi (Nep.)

Damage : 5 holes on the planed surface.

SAPINDACEAE.

Aesculus punduana Wall.

Vernacular names : Kunkri kola Dingri (Nep.)
Ekuhea, Kunkri kola (Ass.)

Damage : 7 holes on the edge of the shooks which had originally been situated nearest to the outside of the trunk.

ANACARDIACEAE.

Mangifera indica L.

Vernacular names : Lowi am (Nep.)
Am (Ass.)

Damage :	Planed surface	...	156 holes.
	Unplaned surface	...	144 „
	Edge nearest outside of trunk		14 „
	Total	...	314 holes.

LEGUMINOSAE.

Albizzia stipulata Boivin.

Vernacular names : Sau, Siris (Nep.)
Sau, Harish (Ass.)

Damage :	Planed surface ...	...	167 holes.
	Unplaned surface	...	104 „
	Edge nearest outside of trunk		60 „
	Total	...	331 holes.

One edge of the shook consisted of very soft wood, and the damage was confined to this portion.

Albizzia procera Benth.

Vernacular names: Safed siris (Nep.)

Damage: 4 holes in the edge which had originally been nearest the outside of the trunk.

Erythrina indica Lam.

Vernacular names: Fullidha (Nep.)
Madar (Ass.)
Palte madar (Beng.)

Damage: No borers had been at work inside the shook, but the planed surface was much etched in the softer parts of the grain by some similar pest.

Erythrina arborescens Roxb.

Vernacular names: Fullidha (Nep.)

Damage: None.

COMBRETACEAE.

Terminalia myriocarpa Hueck. & Muell. Arg.

Vernacular names: Hollock, Jalna (Ass.)

Damage: None.

Terminalia citrina Fleming.

Vernacular names: Hilika (Ass.)
Haritaki (Beng.)

Damage: None.

LYTHRACEAE.

Duabanga sonneratioides Ham.

Vernacular names: Lampatia (Nep.)
Kokon (Ass.)
Ramdaloo (Beng.)

Damage: None.

CORNACEAE.

Nyssa sessiliflora Hook. fil.

Vernacular names : Kalay, chilauni (Nep.)
Pani kadam (Ass.)

Damage : None.

APOCYNACEAE.

Alstonia scholaris R. Brown.

Vernacular names : Chatiwan (Nep.)
Chatwan (Beng.)
Satiana (Ass.)

Damage : None.

BORAGINACEAE.

Ehretia wallichiana Hook. f. & Thoms.

Vernacular names : Boeri, Dowari (Nep.)
Damage : None.

LAURACEAE.

Lindera pulcherimma Benth.

Vernacular names : Sisi (Nep.)
Damage : None.

Machilus bombycina King.

Vernacular names : Soom (Ass.)
Damage : 4 holes situated in the part which was originally nearest the outside of the trunk.

Machilus edulis King.

Vernacular names : Dudri, Lepchaphal (Nep.)
Damage : 2 holes on the planed surface.

Machilus gammieana King.

Vernacular names : ?
Damage : None.

Beilschmiedia sikkimensis King.

Vernacular names : Tarsing (Nep.)
(?) Dumbal (Ass.)

Damage : 2 holes on the planed surface.

Cinnamomum obtusifolium Nees.

Vernacular names : Singoli (Nep.)
Pat Honda (Ass.)
Tezpat, Ramtezpat, Kinton (Beng.)

Damage : None.

Cryptocarya amygdalina Nees.

Vernacular names : Patmero (Nep.)
Bon-soom (Ass.)

Damage : None.

THYMELACEAE.

Aquilaria agallocha Roxb.

Vernacular names : Sasi (Ass.)
Aggar (Beng.)

Damage : None.

EUPHORBIACEAE.

Endospermum chinense Benth.

Vernacular names : Holoidchaki (Ass.)

Damage :	Planed surface ...	...	52 holes.
	Unplaned surface	...	9 ,,
	Edges ...	...	26 ,,
	Total	...	87 holes.

This shook appeared to have been cut from the outside of a log. One edge was much damaged.

Macaranga denticulata Muell. Arg.

Vernacular names : Baura, Modala.
Madala (Ass.)
Burna (Beng.)

Damage : None.

Trewia nudiflora L.

Vernacular names : Gamhar, Kendlo (Ass.)
Pitali (Beng.)

Damage :

Planed surface ...	...	565 holes.
Unplaned surface	...	441 ,,
Edges ...	...	118 ,,
Ends ...	...	13 ,,
Total	...	1,137 holes.

MORACEAE.

Morus indica L.

Vernacular names : Chhota kimbu (Nep.)
Nuni, meshkuri (Ass.)
Tut (Beng.)

Damage : None.

FAGACEAE.

Castanopsis sp.

Vernacular names : Hingori (Ass.)
Damage : None.

CONIFERAE.

Abies pindrow Spach.—The Silver Fir.

Vernacular names : Tos (Punjab.)
Damage : None.

Picea morinda Link.—The Indian Spruce.

Vernacular names : ?
Damage : 1 hole on the unplaned surface.

Pinus excelsa Wall.—The Blue Pine.

Vernacular names : ?
Damage : None.

Podocarpus neriifolia Don.

Vernacular names : Gunsi (Nep.)
Damage : None.

An interesting feature of the results obtained is shown when the woods are arranged in order according to the amount of damage done. It is then readily seen that the woods fall into distinct groups of differing degrees of susceptibility to attack. Group I, of which Simul *(Bombax malabaricum)* is the only representative, may be looked upon as very highly susceptible to attack ; Group II, represented here only by gamhar *(Trewia nudiflora)* as highly susceptible ; Group III as susceptible ; Group IV as slightly susceptible ; and Group V as resistant, for the woods have been exposed to attack for at least six years.

Wood.	No. of holes.	Group.
Bombax malabaricum (Malvaceae)	1,211*	I
Trewia nudiflora (Euphorbiaceae)	1,137	II
Albizzia stipulata (Leguminosae)	331	III
Mangifera indica (Anacardiaceae)	314	III
Garuga pinnata (Burseraceae)	310	III
Endospermum chinense (Euphorbiaceae)	87	IV
Cedrela toona (Meliaceae)	61	IV
Canarium bengalense (Burseraceae)	39	IV
Sterculia villosa (Sterculiaceae)	33	IV
Aesculus punduana (Sapindaceae)	7	V
Echinocarpus dasycarpus (Tiliaceae)	6	V
Acer campbellii (Aceraceae)	5	V
Michelia cathcartii (Magnoliaceae)	4	V
Albizzia procera (Leguminosae)	4	V
Machilus bombycina (Lauraceae)	4	V
Machilus edulis (Lauraceae)	2	V
Beilschmiedia sikkimensis (Lauraceae)	2	V
Picea morinda (Coniferae)	1	V
Magnolia cambellii (Magnoliaceae)	0	V

* This figure would have been much higher had the wood not been treated with rosin varnish in November 1918, by which time there were already 1,086 holes.

Wood.	No. of holes.	Group.
Michelia excelsa (Magnoliaceae)		
Alphonsea ventricosa (Anonaceae)		
Crataeva religiosa (Capparidaceae)		
Sterculia alata (Sterculiaceae)		
Elaeocarpus lanceaefolius (Tiliaceae)		
Amoora rohituka (Meliaceae)		
Erythrina arborescens (Leguminosae)		
Erythrina indica („)		
Terminalia citrina (Combretaceae)		
„ *myriocarpa* („)		
Duabanga sonneratioides (Lythraceae)		
Nyssa sessiliflora (Cornaceae)		
Alstonia scholaris (Apocynaceae)	0	V
Ehretia wallichiana (Boraginaceae)		
Cinnamomum obtusifolium (Lauraceae)		
Cryptocarya amygdalina („)		
Lindera pulcherrima („)		
Machilus gammieana („)		
Aquilaria agallocha (Thymeleaceae)		
Macaranga denticulata (Euphorbiaceae)		
Morus indica (Moraceae)		
Castanopsis sp. (Fagaceae)		
Abies pindrow (Coniferae)		
Pinus excelsa („)		
Podocarpus neriifolia (Coniferae)		

It will be seen from the foregoing table that the simul and gamhar woods were affected to almost the same extent. This was due, not to the two woods falling into the same group, but to the

simul having been treated with a rosin varnish towards the end of 1918.

This varnish was prepared by dissolving rosin in turpentine in the following proportions :—

Rosin ...	...	... $3\frac{3}{4}$ lbs.
Turpentine	...	... 1 gallon.

The varnish was merely applied to the wood with a stiff brush. Applied in this way 1 gallon of varnish was found to cover 500 sq. ft. of surface on roughly planed wood.

The country boxes in general use are of three sizes :—

Large size, 22″ × 22″ × 24″, surface area 21·39 sq. ft.

Medium size, 19″ × 19″ × 22″, surface area 16·62 sq. ft.

Small size, 16″ × 16″ × 20″, surface area 12·44 sq. ft.

1 gallon of varnish would therefore suffice to cover—

$23\frac{1}{4}$ large boxes
or 30 medium ,,
or 40 small ,,

Both the rosin and turpentine were obtained from the Government Turpentine Distillery, Bhowalla, U. P.

The rosin cost Rs. 16 per maund (in 1918) f.o.r. Kathgodam, R. & K. Railway, packed in barrels containing approximately $4\frac{1}{2}$ maunds nett. The turpentine used, and which was quite satisfactory, was No. III, costing Rs. 8 per gallon tin f.o.r. Gallo Factory, near Lahore, N. W. Ry.

One gallon of varnish would therefore cost Rs. 2-12-0 plus freight, putting the cost per box somewhere about

large size	...	... 2 annas
medium size	...	... 1 anna 6 pies
small size	...	... 1 anna

plus cost of application.

When the simul wood was treated on November 27th, 1918, there were 1,086 holes in it, distributed as follows :—

Planed surface	460
Unplaned surface	441
Edge nearest outside of trunk ...	139
" " heart " " ...	17
Top end	15
Bottom end	14

All the above holes were marked, and on March 17th, 1921, the wood was again examined, and, though more than two years had elapsed, only 31 new holes were found, distributed as follows :—

Planed surface	17
Unplaned	8
Edge nearest outside of trunk ...	6
" " heart " " ...	0
Top end	0
Bottom end	0

These holes were also marked, and a fresh examination was made later, on April 29th, 1921, when 94 more holes were seen to have been made, though the period which had elapsed since the last examination was only six weeks. These fresh holes were distributed as follows :—

Planed surface	35
Unplaned "	36
Edge nearest outside of trunk ...	7
" " heart " " ...	1
Top end	10
Bottom end	5

It is thus apparent that the effect of the varnish has now worn off, and the rate at which damage is being done would appear to show that until quite recently the varnish was exercising a protective influence.

There is every justification, from the above figures, for the assumption that the effect of the varnish lasts for, at any rate, two years, and this method of prolonging the life of tea chests is one which merits the consideration of tea shippers.

NOTES ON TEA MANUFACTURE.*

H. R. Cooper, B. Sc., F.C.S.

These notes attempt to give shortly and as clearly as possible a general account of what probably takes place during the making of black tea. The account presents no fresh information, and does not claim to be accurate since there is so much still to be discovered, particularly of the fermentation process. In this account, the fermentation theory of Bernard has been used, since this appears to be best in accord with the facts. It should be borne in mind that this theory and many of the other statements here following are very possibly quite inaccurate, and certainly require confirmation. Yet the process of manufacture indicated is probably not very far from the best likely to be discovered, since all the recommendations made have been tested and checked by taster's reports, and may be considered to have been confirmed by practice. Mann is particularly thorough in adopting the check of the taster's report. In any case it is hoped that these notes may be interesting to many planters, and useful to some, particularly to new-comers to the industry. Criticisms and observation from planters will be welcomed, and may lead to extended knowledge.

Scientific terms which might have made these notes clearer to many, are as far as possible avoided, in the hope that they may be read by a wider circle of planters.

The notes are taken mainly from the work of Mann, Hope and Carpenter and the writings of the Java investigators of the same subject Nanninga, Bernard, Welter and others have also yielded much useful information.

The substances of most importance present in fresh tea leaf are :—

1. Caffeine.

* For a discussion of this and rival theories see *Quarterly Journal*, 1911.

2. Tannin.

3. A substance which on fermentation yields an "essential oil," i. e., an oil which can be distilled with steam, and has the characteristic odour of tea.

1. **Caffeine** is an alkaloid, a white crystalline solid soluble in water, which is used in medicine as a stimulant. Tea is certainly consumed practically solely on account of its caffeine. Yet since caffeine is colourless, odourless, and practically tasteless it has no influence on the colour, taste, or smell either of the dry tea or of the liquor, and therefore has no influence on the quality of the tea as measured by its market price. Similarly alcoholic liquors are consumed on account of their alcohol; yet their value cannot be measured by the alcohol content but depends on flavour produced by other substances, although the amount of alcohol does influence flavour, particularly in spirits.

2. **Tea-tannin** is a white non-crystalline soluble solid which rapidly absorbs water and turns brown when exposed to air. It resembles the tannin of oak-bark, and oak-galls in many respects, but certainly differs from either. Its chemical constitution has not yet been determined and is probably indefinite and variable. In its unchanged state it is responsible for the qualities known as "briskness," and when present in greater quantity "pungency."

The compounds produced from it by oxidation during fermentation are certainly responsible for "cup-colour," and probably for some part of the flavour.

3. The essential oil is responsible for the aroma, and the greater part of the flavour, the essential oil occurs in very small quantities, and has been little investigated.

These two latter substances offer fields for investigation, of very great interest, but of great difficulty.

It is clear that the quality of manufactured tea depends mainly on the quality of the fresh leaf. Perfect manufacture, however, will waste as little as possible of the essential oil and of the tannin and its fermentation products; will adjust the length of fermentation so that there is a nice balance between "cup-colour"

and "briskness;" will take care that nothing is introduced which would spoil the tea; and will turn out the tea in a mechanical condition likely to please the market for which it is intended.

The manufacturing process commences from the moment the shoot is detached from its stalk by plucking. The plucked leaf must be preserved from undue drying by keeping as cool as possible, and must not be bruised or broken by careless handling. If so bruised the fermentation process commences, and as the broken leaf may then undergo a fermentation of over 24 hours, it may be readily understood that it is spoilt. Leaf also should not be close-packed so that it gets into a hot, moist state favourable for the development of harmful bacteria.

Withering.—The evidence at present available points to some enzyme as the agent causing the oxidation which occurs during fermentation. Mann supposed this enzyme to be a "non-living" substance occurring naturally in small quantity in the juice of the green leaf. During withering the enzyme increases in amount. This increase Mann seems to have ascribed to a merely chemical action. The active principle in that fermentation (of sugary liquids such as malt "mashes," and grape juice) which produces alcohol from sugars, is also an enzyme; but in that case the enzyme is produced during the growth of a micro-organism—ordinary yeast. Though the yeast is a living organism yet the enzyme produced by it is a non-living substance, and the non-living juice squeezed out of yeast, will produce the same fermentation as yeast itself.

Bernard found that on leaf in the garden in small quantities, and in fermenting tea in large quantities, there always occur yeast-like micro-organisms, and his theory that fermentation is produced by these organisms appears more probable than that of Mann. Both agree that no bacteria are concerned at any rate with the main process and indeed the only bacteria actually found in fermenting teas up to the present, spoil the tea if fermentation is carried on too long. Such bacteria, for example, produce sour teas. At any rate it is certain that a proper withering time is essential to the production of good tea, and under either of the above

theories the reason is that the enzyme must be allowed to develop before fermentation is commenced, in order that proper fermentation may be complete before any harmful bacteria present have had time to act upon the tea sufficiently to spoil it.

The proper withering time can generally be foretold with sufficient accuracy by managers of experience: and experience generally has confirmed a table given by Mann. The number and kind of yeast-like organisms occurring on leaf in the garden may vary, and other factors may also cause variation, and as it appears that in practice an excess of one or two hours affects quality little, this table gives a good enough approximation to work to.

Correct withering time.

Average mean temperature.	Very dry weather or with wind.	Ordinary withering weather.	Atmosphere saturated.
80° F.	19 hours.	19½ hours.	26¼ hours.
81° F.	18 ,,	18½ ,,	25 ,,
82° F.	17 ,,	17½ ,,	25¼ ,,
83° F.	16 ,,	16½ ,,	22½ ,,
84° F.	15 ,,	15½ ,,	21¼ ,,
85° F.	14 ,,	14½ ,,	20 ,,

Mean temperature is half the sum of the highest and lowest temperatures occurring during the withering time.

The average is about 18 hours.

In this time leaf is chemically ready for rolling, but this time does not necessarily produce leaf in the best mechanical condition for getting a good twist on the leaf instead of breaking it up during rolling. For example, with a saturated atmosphere and a temperature of 80° F. leaf will have dried very little in 26 hours, so that it is too brittle to roll; yet, if the leaf is left longer, quality will suffer. On the other hand it may be possible by withering in a a current of hot air to get leaf apparently "ready" in say 8 hours. The quality of such tea will be poor, because sufficient enzyme has not developed. From such leaf under fermented teas may be expected if the normal fermentation time is given; or if the fermentation time is extended there is a risk of the tea being utterly spoilt by the action of harmful bacteria. In practice it is usually not

very difficult so to spread the leaf that it dries at a rate which will bring it into good condition for rolling in a time not very different from what is thought to be the best chemically—say 18 or 20 hours. Under such conditions of saturated atmosphere as occur during the height of the rains in the Dooars, that is when leaf left to itself would never be "ready" in reasonable time, the best procedure is probably to allow the leaf to lie spread normally for a few hours short of the best withering time (in order to allow the enzyme to develop), and then rapidly to dry it into a good condition for rolling, in the artificial current of hot air.

Where owing to shortage of machinery, leaf has to be pushed through, whether ready or not, quality cannot be expected.

Leaf must, of course, be so spread that all dries at about the same rate, otherwise uneven teas will be produced.

The soluble matter, and the soluble tannin increase during normal withering, but as soon as the leaf becomes unduly dry, both soluble matter and tannin decline. For this reason, again, broken or bruised leaf will make poor tea.

Leaf as brought in, contains an average of about 76 per cent. water, and during normal withering dries till the water content is about 60 per cent.

Should leaf become too dry during withering there is a possibility that the cells will become so empty of water that the cell-walls will collapse instead of bursting when rolled.

Where good tea is made, "chungs" appear to be generally preferred to racks for withering. On racks some shoots will hang down through the wires, become overdried, and so spoilt; otherwise there is probably little in it.

Rolling: During rolling some of the cells of the leaf are burst by the pressure, the juice expelled, and spread evenly over the surface of the leaf. It is thus brought into contact with air, and with the enzyme. The enzyme causes oxidation of the tannin, and thus fermentation has commenced.

At the same time the leaves are rolled up so that when dry, unbroken tea has the appearance of a bunch of wires. In times

past great care had to be exercised during rolling so that as much of the tea as possible was so rolled, and not broken up. With present-day harder rolling more of the tea seems to be broken up, and this would tend to increase the percentage of "fannings" and broken tea, both of which give better liquors than a close-rolled leaf-tea, and on the present market get better average prices.

The harder the rolling, the more juice is expressed, and thus more of the tannin will become exposed to rapid oxidation, and liquors of stronger colour are produced.

Overhard rolling is thought to lead to loss of tip, and this may be easily understood, since the darkening juice gets rubbed into the hairy tips, and the tips may even become crushed up, or at least have the fine hairs removed. With the present preference for strong liquors, fairly hard rolling seems to be in general favour; but for markets asking chiefly for appearance, lighter rolling is to be preferred.

Fermentation: As has already been indicated, the most important change taking place during fermentation is an absorption, by the tannin, of oxygen from the air under the influence of an enzyme naturally present on the leaf, and developed during withering.

By this oxidation the pungent colourless tannin is changed to a brown substance, which gives colour and probably some of the flavour to the liquors, but has no pungency.

The same change, naturally, also effects the colour of the infused leaf.

It follows, therefore, that underfermented tea, while retaining high pungency, will give poor cup colour; while the infused leaf will keep a greenish colour.

Overfermented tea, on the other hand, will develope strong colour at the expense of the tannin, and will therefore yield "soft" liquors. At the same time as this change is proceeding, the essential oil responsible for aroma is being developed, but it is not known whether the development of essential oil is due to the same or any enzyme action.

It seems fairly clear, therefore, that the quality of tea must depend chiefly on the quality of the fresh leaf, that this leaf must originally contain a sufficiently high percentage of tannin to yield good colour and still retain sufficient unchanged tannin to make the liquors brisk.

The development of aroma also must depend upon the presence of some substance in the original leaf, though there are possibilities of increased knowledge, leading to some slight change in manufacture which may cause a more complete development of aroma than is always obtained at present.

Fermenting tea, however, not only contains the yeast-like organisms discovered by Bernard, but also swarms with other micro-organisms including bacteria, and certain of these last are capable of spoiling the tea.

Bacteria require time in which to develop sufficiently to produce much effect, and their rate of increase becomes much greater as temperature rises. Both theory and practice point to two methods of reducing damage by bacteria—rapid fermentation, low temperatures, and cleanliness. The rate of fermentation depends upon the amount of enzyme present; hence the necessity of long withering time, and the fermenting floor may here also play a part, since it would naturally be impregnated with the yeast-like organisms.

This possibility was not considered by Mann who assumed the increase in enzyme during withering to be not connected with the growth of a micro-organism, and hence advised fermentation under conditions such that all micro-organisms were excluded so that fermentation took place under aseptic conditions.

The great majority of planters are of opinion that the fermenting floor does have an influence, and that a new fermenting floor yields poorer teas for some time. Cases are indeed met with where fermentations on white tiles at new factories have not led to noticeable loss of price, but such a widespread opinion probably has some foundation in fact, and for this reason the micro-organism (of Carpenter and Bernard) theories are considered as better in accord with facts than Mann's; but Mann's warnings as

to the possibility of harm from bacterial action, cannot be disregarded, and reasonable cleanliness should certainly be observed in the factory.

A fermenting floor or a "kutcha" sorter giving anything approaching a sour smell certainly needs more frequent cleaning, since it may easily introduce a taint into the teas. At the same time Mann's recommendation to sterilize the floors completely by scalding seems contrary to the present evidence.

Fermentation is influenced by

1. air-supply,
2. temperature,
3. time.

1. Air-supply: Since fermentation is an oxidation process, a good supply of fresh air must be ensured by ventilation. It must, however, seldom occur in practice that the air-supply is deficient.

A draught should certainly be avoided since it would tend to dry out the leaf.

Mann's suggestion of wet clothes is sound, since not only do they keep the fermenting room cool, but keep the atmosphere saturated, and so prevent drying out.

2. Temperature: Mann has shown that the best fermenting temperature is between 78° and 82°F., although little harm is apparent between 76° and 84°F.

In the manufacturing season this temperature is below the normal shade temperature, and therefore the fermenting room must be kept cool artificially, and this is normally done by means of sun-proof roofs and walls, and hanging wet clothes. The floor, particularly when wet, is of course cooler than the upper air, and little difficulty is usually experienced in keeping the fermenting leaf at about the right temperature in the fermenting house.

More care might sometimes be exercised while the leaf is in the rollers, which are sometimes placed in a quite warm part of the factory. Some factories arrange for a stream of cool air to play on the rollers, and results are thought to be favourable.

Where the shade temperature is below 75° the fermentation temperature may be increased by spreading the leaf thicker, and thus utilizing the heat developed by fermentation to keep the temperature of the leaf above that of the surrounding atmosphere. At higher temperatures leaf should be spread about $1\frac{1}{2}$ inches thick, both to avoid undue rise in temperature and to ensure even fermentation.

3. **Time**: There is at present no exact method of ascertaining when fermentation is complete, and the best guide is a practised nose, since fermentation is complete soon after the development of maximum aroma. In Java fermenting time varies greatly, being in some factories complete when the leaf leaves the rollers. In North-East India there is not so much variation.

The essential oil responsible for aroma begins to increase very rapidly when rolling commences, and the rate of production slows down as fermentation proceeds till the amount of essential oil reaches a maximum in about 3 hours from the commencement of rolling. After this time it begins to decrease, sometimes only slowly, but in some cases rapidly. Mann has suggested that a rapid loss of essential oil is due to the action of harmful bacteria. For the production of maximum aroma, then, fermenting time should not exceed 3 hours, and this is probably about the best time for the production of teas, of which the main selling quality is aroma. But this time will not usually suffice for the production of good liquors, and teas to be sold for liquors require usually about 4 hours or $5\frac{1}{2}$ hours at the most. Fermentation time, of course, counts from the commencement of rolling. At present, unfortunately, no rule can be given for determining the optimum time of fermentation and no doubt it varies for different factories and different seasons; but in most factories past experiment has led to the adoption of a standard time which has been found to yield teas bringing the best average prices.

Tea, once it has been rolled, should never come into contact with iron, or a darkening of the liquors occurs. It may be remembered that ordinary old-style black ink is a compound of iron and tannin, and we do not require ink in our teas.

Firing: When the leaf is placed in the dryer, it is in such a state, that further fermentation even at a low temperature would lower quality, while fermentation for any length of time at a high temperature will completely ruin it.

The first requirement of a drier, therefore, is that it shall rapidly raise the temperature of the leaf sufficiently to stop fermentation altogether.

Mann has shown that this temperature must certainly be over 150 and it is probably better at about 180°F. On the other hand the temperature should not exceed 180°F. or the loss of essential oil is greatly increased. These are temperatures in the leaf, which by evaporation is kept at a lower temperature than that of the hot air surrounding it.

Once fermentation has been stopped the problem then is to remove the water as rapidly as possible. Any 'stewing' of the leaf results in loss of quality. While any great quantity of water remains the rate of loss of essential oil is very rapid, while the loss from '12-anna fired' leaf is comparatively slow.

At the same time it is not advisable to produce too rapid drying, or there is danger of 'case-hardening'—the production of a dry layer (only slightly pervious to water-vapour) on the outside of the leaf, which prevents rapid evaporation of the water locked up in the cells in the middle of the leaf.

Hope and Carpenter recommended for machines of the Paragon type a 'machine temperature' of 200°F.; or, where flavour is the chief consideration, 220°F. since it is then essential that no fermentation shall go on at the high temperature of the machine.

At these temperatures thin spreading of the leaf is essential, trays must be moving at their fastest, and there must be a definite forced current of air passing over the trays.

With thicker spreading, temperatures must be higher, but quality is liable to be lowered.

Tea after final firing contains an average of 2 to 3 per cent. moisture, but rapidly absorbs more from the atmosphere and when allowed to stand in the house Mann showed that the moisture

content of most tea rose to $9\frac{1}{2}\%$ after 15 hours, and $16\frac{1}{2}\%$ after $5\frac{1}{2}$ days.

Tea after making undergoes changes.

A 'post-fermentation,' due to some enzyme which escapes destruction during firing, undoubtedly goes on in made teas, and leads to improvement. This enzyme requires a certain moisture content in the leaf. Too great a moisture content, on the other hand, leads to deterioration of the tea, and excessive moisture allows the production of mouldy tea.

Welter produces very strong evidence that teas should be packed at a moisture content not higher than $6\frac{1}{2}$ and 7 per cent. The lead lining of the boxes should of course be air-tight so that no further absorption of water takes place.

Many determinations made on teas as they arrive on the market show that the best teas do actually contain about $6\frac{1}{2}$ to 7 per cent, moisture.

Recent market reports shows that this matter is of particular importance just now when teas may be put up for sale very long after making, and many teas which undoubtedly would have been of high quality arrive spoilt.

The adoption of the suggestion made by Hope and Carpenter in 1911 for the purchase of a balance and drying oven, by every factory, for determining the moisture content of teas before packing would certainly now lead to great saving. Any intelligent school-boy can be trained to carry out the simple determination. Similar work is always done by Assamese boys, straight from school in this department's laboratories.

One other point should be borne in mind. Tea, whether '12-anna fired' or final fired, deteriorates rapidly at temperatures above air temperatures, and should therefore not remain longer than absolutely necessary, in big heaps, in the interior of which temperature remains high for some time.

Appearance: Grading and sorting are not within the scope of this article. They are purely commercial problems. There are,

however, one or two factors affecting appearance which are of some scientific interest.

Even teas can, of course, only be produced by even work even firing.

For all these thin spreading is necessary so that there is no difference between the inside and the outside.

The preference shown by the present market for broken teas, and even dusts, is perfectly logical, since the more finely the tea is divided, the stronger and better is the liquor extracted from it by boiling water. In fact the reason why all tea is not preferred in the form of dust, is probably prejudice mainly connected with doubt as to its perfect purity and cleanliness. Ordinary dust as now sold, of course, comes from all grades of tea and therefore will not possess the flavour of fine teas obtained by sifting rolled leaf, which process separates out young leaf.

Estimations of tannin and total soluble solids in the extract give a very fair idea of the 'liquoring qualities' of a tea. Dusts give an average of about 27% tannin and 45% total solids; Broken orange pekoe averages about the same in tannin, and about 43% total solids, while a pekoe souchong averages about 22% tannin, and 40% total solids.

Important factors which logically affect quality as judged by appearance are 'stalk' and 'tip.'

Stalk is more or less rightly regarded by the public as in the nature of an adulterant. While there is some reason for believing that stalk will give more flavour than some leaf, stalk always contains distinctly less tannin than leaf does.

The golden coloured fragments occurring in high grade teas, owe their appearance to a mass of tiny hairs on the tips of buds and very young leaves. Teas showing a large proportion of 'tip' must therefore be made from young leaf, and other things being equal young leaf makes better tea than old leaf.

FUNGUS BLIGHTS OF TEA IN NORTH-EAST INDIA DURING THE SEASON 1920.

S. C. BOSE.

It is very regrettable that only a very few tea gardens sent mycological reports for the season under review. The exceptions were some Cachar and Sylhet plantations. Further, the Mycologist was on home leave for the latter half of the year and during the first half he could not do much touring, which fact contributed towards a paucity of such detailed information as has been obtained usually in previous years. However the following notes, though somewhat incomplete in detail, will furnish some idea of the nature and extent of blights in the past season. It should be noted that the number of reports received up to February 1921, has been disappointing and the fact cannot be too strongly emphasised that unless reports are regularly sent by a large number of planters it will detract much from the value of the seasonal report.

LEAF DISEASES.

BLISTER BLIGHT.

(*Exobasidium vexans*).

DARJEELING AND TERAI.—Although no information was received, surely the blight must have been present in many gardens.

JALPAIGURI AND DOOARS.—No reports were received.

ASSAM.—Specimens were received from several gardens in Sibsagar, Jorhat and Golaghat. The blight was in evidence about the middle of March and disappeared about the end of August. The blight has been spreading steadily southwards and it is interesting to note that it has reached Lettekujan, where it was not seen before.

CACHAR AND SYLHET.—Till now the blight had not been found in these districts. But it has now been reported from one

garden in North Cachar where it was said to be prevalent in a certain shady section with jungle on both sides. The disease attack was of moderate intensity. As no specimens were sent for examination it is uncertain whether the disease found was actually blister blight.

Copper blight.

(Laestadia camelliae.)

Darjeeling and Terai.—No reports were received.

Jalpaiguri and Dooars.—Specimens were received from one garden in Jalpaiguri, where it was serious in certain sections.

Assam.—Specimens were received from one garden in Sibsagar.

Cachar and Sylhet.—It was common in these districts. It was serious in one garden in North Sylhet where it caused considerable damage. The disease appeared at the end of April. It was kept in check for some time by plucking off all diseased leaves and burning them and was thought to have been thoroughly stamped out at the end of July, but during a long spell of wet weather from 1st to 20th August it re-occurred again and disappeared upon the advent of dry weather in October. It attacked all jats of tea, the good jat being more susceptible.

Brown blight and Die-back.

(Colletotrichum camelliae = Glomerella cingulata, Gloeosporium Sp.)

Darjeeling and Terai.—No reports were received.

Jalpaiguri and Dooars.—Specimens were received from two gardens in Jalpaiguri.

Assam.—No Mycological report was received. But the blight was common all over the district. It was not so bad as in the previous year.

Cachar and Sylhet.—It was common in both the districts but was worst on certain weak, low lying, shallow rooting

sections. The blight appeared in March and remained throughout the year. Manipuri and Assam indigenous were less affected than hybrid.

Specimens of this disease were also received from one garden in Chittagong and another in Travancore. This blight caused some damage to seedlings in some districts. It was also found on the root of a dead tea bush. It was also observed on *Albizzia procera.*

GREY BLIGHT.

(Pestalozzia theae).

DARJEELING AND TERAI.—No report was received.

JALPAIGURI AND DOOARS.—Specimens were received from one garden in the Dooars.

ASSAM.—Specimens were received from one garden in Sibsagar. Very little of the blight was present.

CACHAR AND SYLHET.—Slight in many gardens.

RIM BLIGHT.

(Alternaria Sp. and Physiological causes).

DARJEELING AND TERAI.—No report was received.

JALPAIGURI AND DOOARS.—No report was received.

ASSAM.—Present to a slight extent in some gardens in Jorhat.

CACHAR AND SYLHET.—Present to a slight extent in one garden in Lakhipur.

BLACK ROT.

(Hypochnus theae).

DARJEELING AND TERAI.—No reports were received.

JALPAIGURI AND DOOARS.—No reports were received.

ASSAM.—No reports were received.

CACHAR AND SYLHET.—Found in one garden in Chargola. It did very little damage.

STEM DISEASES.

CANKER.

(Nectria cinnabarina and Nectria, Sp.)

DARJEELING AND TERAI.—It was observed in one garden in Darjeeling.

JALPAIGURI AND DOOARS.—No reports were received.

ASSAM.—No reports were received.

CACHAR AND SYLHET.—It was found in one garden in Cachar.

STEM CALLOSITIES.

(Causes unknown.)

DARJEELING AND TERAI.—It was observed in one garden in Darjeeling.

JALPAIGURI AND DOOARS.—No reports were received.

ASSAM.—No reports were received.

CACHAR AND SYLHET.—It was common in Hailakandi, the Longai and Chargola Valleys of Sylhet and in Lakhipur and Happy Valley of Cachar.

Specimens were also received from one garden in Travancore.

RED RUST.

(Cephaleuros Mycoidea.)

or

(Cephaleuros virescens.)

DARJEELING AND TERAI.—No reports were received.

JALPAIGURI AND DOOARS.—No reports were received.

ASSAM.—Specimens were received from one garden in Sibsagar.

CACHAR AND SYLHET.—It was present in both the districts. This disease was not reported as severe anywhere.

THE NATURE OF SOIL ACIDITY IN NORTH-EAST INDIA.

P. H. CARPENTER, F.I.C., F.C.S.

AND

C. R. HARLER, B. SC., A.I.C.

INTRODUCTION.

A great deal of work has been done and a great number of theories have been put forward in connection with soil acidity. Most of the workers have carried out their experiments in temperate climates and with soils not subjected to tropical and sub-tropical conditions. Whilst the methods which have been devised are doubtless capable of estimating certain forms of soil acidity they do not give results which may be satisfactorily interpreted in the field so far as North-East India is concerned.

The investigation described in this paper has been carried out with a hope of elucidating the particular nature of the soil acidity that occurs under the conditions prevailing in the North-East India tea districts and of obtaining a means of removing or inhibiting the action of this acidic body.

The factors that produce what is known as soil acidity are doubtless many, but they are all included under this one comprehensive term since they possess the common property of turning blue litmus red. It was probably this similarity that led to the introduction of the term. The litmus test was probably the earliest used to determine soil acidity. At the time of its introduction the ionic theory and colloid chemistry were undeveloped and both these factors have important connections with the problem.

The earliest ideas of soil acidity are connected with the theories of humic acid and similar bodies formed from the organic

matter in the soil but it soon became evident that many soils possessing but very little organic matter whether measured by loss on ignition, direct determination of carbon or by the Grandeau method or one of its modifications possessed very markedly those properties that were comprehended under the term soil acidity and which were rectified wholly or in part by the application of lime or some free base to the soil.

Soil acidity then, as first defined, resolved itself into a question of hydrogen ion concentration and various methods have been devised to deal with this aspect of the problem even to direct titration of soil extracts with alkali. It was very soon evident that such a simple explanation of the phenomenon was very far from the truth and that whilst in a few soils with a very high content of organic matter the determination of hydrogen ion might afford an approximation to the actual soil acidity yet in the vast majority of cases this was not so.

Other theories were then formulated which resulted in other methods being devised and particularly must be mentioned those based on the supposition that soil acidity is due to the presence of silicic acid or of acid silicates. This theory doubtless accounts for a great part of the acidity met with in many soils for, with sufficient hydration, many silicates and possibly some of the weaker bases assume acid properties. This type of acidity results in many cases from weathering.

Later workers, and particularly Connor (1), Abbot (2), and Daikuhara (3), have investigated another aspect of the question and the capability of iron and alumina entering the soil solution as acid silicates in the absence of sufficient quantities of lime and magnesia is given as the cause of soil acidity in some areas. The addition of salts of strong acids to these soils increases the amount of the weak bases iron and alumina in solution and results in a depression of crop.

Soils which are fundamentally different naturally have different types of acidity in which one or the other of the factors mentioned above predominates. All types of acidity, however, are the same in that they are alleviated wholly or in part by lime.

The position is summed up as follows by Hoagland (4) :—

"In perhaps the majority of cases the inhibition of crop growth frequently associated with acid soils may not be the direct effect of the acidity at all. In other factors, such as soluble aluminium, may be found the true direct cause of the injury. It is granted that these causes may be removed by exactly the same treatment which neutralises the acidity, but in the interest of scientific progress it is essential to separate and designate the various factors and their inter-relations.

"Is it not possible that the whole subject would become clarified if we attempted to reach such definite conclusions as: 'The growth of the crop is inhibited by too great concentration of hydrogen ion, or by too large a concentration of aluminium ion, or by too low a level of calcium in the soil solution, or by the effect of the hydrogen ion concentration on the soil micro-organism, etc.' ?"

Before proceeding to discuss the various methods employed in estimating soil acidity and their applicability to the soils of North-East India, it is necessary to give a brief account of the geology and meteorology of the district for these factors are of fundamental importance.

The Tea Districts of North-East India.

The area under tea in North-East India may be roughly divided into four districts :—

(i) *Darjeeling Hill District.*—The hill districts of Darjeeling are situated in the lower ranges of the Himalayas where tea is grown on the hills from an elevation of 5,000 feet down to a level, in the deeper valleys, but little above that of the plains of Bengal. In this district, subject to great fluctuations of temperature and rainfall, the soil is derived from gneiss rocks or as one more nearly approaches the outer line of hills from sandstone or the shale rocks of the Daling clay series.

(ii) *The Dooars and Terai.*—This includes the gently sloping land that extends from the foot of the outer ranges of the

Himalayas to the plains of Bengal proper. This area, known as the Bengal Terai and Dooars, extends across the whole of the Northern boundary of Bengal from Nepal on the West, to Assam on the East. It is a narrow belt not exceeding 20 miles in width. It is characterised by high rainfall, approximating 200 inches during the wet season of the year, June to September, and by an almost entire absence of rain during the remaining months of the year. During the hot, dry weather immediately preceding the wet season the temperature is high and continues high throughout the wet period. The soil in this district can be divided into two distinct kinds, which can best be referred to as old and new alluvium.

The old alluvium or, as it is generally termed, Red Bank soil which is high plateau land in the West Central Dooars, is of a red colour and is characterised by a high percentage of clay and usually of coarse sand. It is a very fertile soil, but under cultivation readily loses its initial fertility not from the loss of plant food material but because the plant seems to be incapable of making use of it. The acidity of these soils, as determined by the modified Albert method is high, the maximum being about 5,000.

The new alluvium which is a recent soil and has been deposited by the rivers from the Himalayas in their southward journey to the sea is of a sandy or silty nature, of a grey or yellow colour and is situated at a lower level than the old alluvium. These soils vary much in their composition, some being rich in plant food whilst others are comparatively poor. They are subjected to the same climatic conditions as the Red Bank, but although the weathering process has not proceeded so far, they are, however, like the Red Bank soils generally poor in lime. The acidity as measured by the Albert method is not so high as with the older soils, the maximum being about 4,000 and the average figure about 2,000 whilst a few soils of very recent deposition have an alkaline reaction.

(iii) & (iv) *The Brahmaputra and Surma Valleys.*—These areas are described (5) as follows :—

" The Brahmaputra Valley is at a considerably higher elevation above sea-level than the Surma Valley, and the fall is consequently

greater. The following are the heights above mean sea-level of the chief points (at the surface of the alluvium) in the Brahmaputra Valley :—

	Feet.		Feet.
Sadiya ...	... 440	Buramukh, near Tezpur	... 256
Dibrugarh ...	... 340	Gauhati ...	... 163
Sibsagar ...	... 319	Goalpara ...	... 150

"The Valley has thus, in a distance of about 450 miles, a fall exceeding 300 feet. In the Surma Valley, on the other hand, the following are the heights :—

Silchar ...	... 87 feet.	Sylhet ...	... 48 feet.
Chhatak	... 41 feet.		

"In consequence of this greater fall, the rivers in the Brahmaputra Valley tend to cut away their banks, while those in the Surma Valley tend to raise them. The former is most correctly described as in great part a gigantic *khadar*, or strath, within which the river oscilates to and fro, while the latter is a delta in the process of formation. Nearly the whole of the central portion of the Brahmaputra Valley consists of fine greyish-white sand, lightly covered by a layer of clay. Away from the river the alluvium is more consolidated, and clay, due to the decomposition of the sand, predominates. Throughout this surface there are found here and there (as in the southern portions of the Sibsagar district, in the plain of Bishnath, and in the ridge of Tezpur) more elevated tracts, which seem to represent a more ancient *bhangar*, or older alluvium, the greater part of which has disappeared. Such places where they have been laid bare by the river are easily distinguishable, by their closer and heavier texture and by their higher colour, from the shifting grey sands of which the rest of the trough is composed, and are often indicated by a name chosen for their peculiar feature (Ranga-mati, "coloured earth," Ranga-gora, "coloured bank").

"In the Surma Valley the process of deltaic formation (whether because depression of the surface has proceeded *pari passu*, with alluvial accretion, or because the deposition of silt is slower and less copious than in the central portion of the Gangetic delta)

is less advanced than anywhere else in the great alluvial plain. As already explained, the river banks are almost the only high land (always, of course, excepting the *tilas* and hill ranges) in the valley, and behind them lie great basins, or *haurs*, which are deeply covered with water half the year. In the flood season the rivers drain into these *haurs* and there deposit their silt, the water emerging when the river falls perfectly clear. This process results in a very noticeable raising of the level of these basins; the Chatla *haur*, a great depression in South Cachar, which receives the floods of the Barak, is said to have risen 18 inches in the ten years ending 1882-83, and almost another foot during the last decade; the extensive Hakaluki *haur* in South Sylhet, which receives the Langai, is likewise steadily diminishing in depth. One remarkable event in the history of Western Sylhet was the diversion of the Brahmaputra, which, till the commencement of the last century, flowed east of Mymensingh, and of the great tract of old raised alluvium called the Madhupur Jungle, into a new course far to the west. Previously to this diversion, which has now brought the Brahmaputra, as a delta-forming agency, into direct competition with the Ganges, the former river threw the greater portion of its lighter silt into the *bheels* of West Sylhet, and thus co-operated in raising the region. Now the Surma Valley depends for its accretions on the purely rain-fed floods of the minor rivers which traverse it, and which are, of course, far inferior as silt-bearers to the great glacier-fed streams that drain the mighty chain of the Himalayas."

The acidities in the Brahmaputra Valley vary with the heaviness of the soil. The Tezpur Red Bank and the parts higher up the valley (*e. g.* Numaligarh) where the older alluvium crops out show values up to 4,000, but the general tendency is for the acidity to be in the neighbourhood of 1,000 for the light soils met with in this valley. However, variation occurs with rainfall as is mentioned on page 139.

The peat soils of the Surma Valley show acidities of about 4,000, but in the discussion which follows these cases are not considered, for the acidity is of an organic type and not comparable with that generally met in other parts under consideration.

The soils in both Valleys are, by English standards, poor. Here again the peat soils are not included.

The question may now be asked—What is a tea soil? Tea does not need a rich soil, although naturally it flourishes better in a rich than a poor soil, but it is unable to grow luxuriantly and with little attention unless there is a good rainfall in March, April and May. It is unable to withstand the drought experienced generally in North-West India.

Along the slopes of the Himalayas and in the Surma Valley, the country is open to the breezes from the Bay of Bengal and the rainfall is satisfactory. In the Brahmaputra Valley the rain is either brought by way of Dhubri round the Garo Hills or by way of the Jetinga Valley. In the former case most of the precipitation takes place on the north bank of the River. In the latter case the fall decreases as the valley is ascended, but the influence of the former wind increases. The net result is an increase in rainfall from Golaghat to Dibrugarh. Immediately in the shadow of the Shillong plateau the rainfall is very low and on the Lanka plain it is no more than 30 inches. At Golaghat the fall is 60 inches and below this tea will not grow luxuriantly.

Soil Acidity Methods.

Soil acidity methods fall roughly into two groups—one set of methods measuring the strength or intensity of the acid and the other set measuring the quantity of the acid.

The strength of the acid is usually measured by Sörensen's method (6) which gives the P_H value for soil solution. Rice and Osugi (7) measure the rate of inversion of cane sugar. After the soil has been neutralised the inversion continues and this is explained by the authors as being due to acidity bound up with the solid phase, which acidity is not measured by other methods.

Another method which claims to measure hydrogen-ion is that depending on the liberation of iodine from a mixture of potassium iodide and iodate.

These methods do not agree among themselves, neither do they correspond with the amount of calcium bicarbonate necessary to neutralise the soil as has been shown by Hoagland and Sharp (8).

The methods which aim at determining the lime requirement of soils are distinctly in advance of those mentioned, for the term "lime requirement" takes a much broader view of the problem and does not amit of the narrow sense implied by the term "acidity."

The method of Veitch (9) is most used in America and consists in the treatment of soils with calcium hydroxide till the reaction is just neutral. By this process any hydrogen ion will be removed, part of the lime will be exchanged for potash, soda, magnesia, alumina and iron and part will be wholly absorbed. The method is very drastic and varies with the strength of base used. In addition the process is somewhat tedious. On this account it was modified by Albert and later by Lyon and Bizzel (10). The application of this method to soils of North-East India is discussed fully below. Truog (11) apparently recognising the severity of Veitch's method employed baryta for one minute during which period he claimed to measure the active acidity. Tacke (12) uses pure calcium carbonate and McIntire (13) calcium bicarbonate.

With all these methods, the lime requirement fails to denote what is actually needed in the field. They are all so drastic that the particular factor which they aim at estimating is masked by the number of latent factors which are brought out. With the soils of North-East India experience extending over many years and involving thousands of acidity estimations by the modified Albert method has shown that practically the same lime treatment does for a soil showing a lime requirement of 1,000 as for one showing 2,000. On the Red Bank where the lime requirement reaches 4,000 parts per million, the addition of lime in excess of 800 lbs. per acre (about 250 parts per million) led to a distinct depression in crop. Thus the lime requirement figure tells little more than could be gathered from the litmus test.

Hopkins (14) treating the soil with potassium nitrate and Jones (15) using calcium acetate estimated the lime requirement

by acting on the acid silicates in the soil and replacing the weak bases by the strong bases potash and lime respectively. The salts formed being composed of weak bases and a strong acid are titrated with standard alkali.

Stephenson (16) compares the various methods and comes to the conclusion that Tacke's method is the best for the soils he examines. The comparative results are shown under :—

Tacke	100
McIntire	85·4
Veitch	108
Truog	283
Jones	89·7
Hopkins	46·5

By comparing the first four figures it is seen how much the lime requirement varies according to the method used. Chemically these methods are very much alike. The variation between the values given by the Hopkins and Jones methods are also due partly to differences in concentration of the reacting solutions. By adjustment, these methods can be made to fit the lime requirements of the soils of any area.

None of these methods give satisfactory results with the soils of North-East India. The estimation of the hydrogen-ion is inadequate for the soils under consideration are not truly acid although they require lime or some treatment which gives the equivalent action of lime so far as the soil solution is concerned. Any acid arising from the organic matter would be extremely small.

The Significance of the Albert and Hopkins methods with the Soils of North-East India.

Meggitt (17) in his study of the acid soils of Assam employed the Veitch method and from field experience found that the lime requirement was about one-third that denoted by the method.

The Scientific Department of the Indian Tea Association has during the past 10 years employed the Albert method which as modified by Lyon and Bazzel gives the same results as the Veitch

method. Although it is realised that the results given by the modified Albert method do not measure the cause of the acidity of the soils under consideration, experience of the various districts makes it possible to fix the lime requirement from the figure obtained.

The method used involves the digestion of the soil for one hour on a water bath with $N/20\ Ba(OH)_2$. An excess of ammonium chloride is added and the ammonia liberated is a measure of the unabsorbed base. A blank experiment without the addition of baryta is also made. Now if ammonium chloride alone is boiled with water, some ammonia is liberated but when boiled with the soil still more is liberated, so a constant blank cannot be taken. The blank increases with the heaviness of the soil. It is unlikely that this extra ammonia comes from soil itself for distillation alone or with another chloride (*e.g.* sodium chloride) fails to liberate any ammonia. The action of ammonium chloride on the soils under consideration is a complicated one, involving as Carpenter and Harler (18) have shown the liberation of iron, alumina, lime, magnesia and potash in about equivalent quantity to the amount of base fixed in the case of light soils although with heavier soils an appreciable quantity of the whole ammonium chloride molecule is fixed. These reactions will not involve the liberation of ammonia, which is essentially the reaction of a base.

Under the conditions of the experiment ammonia equivalent to 1·1 cc. $\frac{N}{10}NH_3$ is liberated from NH_4Cl alone. With Tocklai soil—a light sandy loam—6·5cc. are envolved. The acidity is calculated as follows and the values for the Tocklai example are given :—

$$\begin{array}{lll} \text{Soil} + \text{baryta} + NH_4Cl & - 49{\cdot}35 \text{ cc. } \frac{N}{10}NH_3 & \text{evolved.} \\ \text{Soil} + NH_4Cl & - \ \ 6{\cdot}05 \text{ cc.} \quad ,, & ,, \\ \text{Baryta alone} & - \ \ 50 \text{ cc.} \quad ,, & ,, \end{array}$$

$$\text{Acidity} = \{50 - (49{\cdot}35 - 6{\cdot}05)\} \times 112 = 750.$$

Thus it is seen that the greater the blank, the greater the acidity, and in most cases the greater part of ammonia liberated in the blank is due to the soil itself and is a measure of basicity. Hence it is incorrect to add this quantity to the acidity.

The table below shows the acidity of the borbhetta plots, referred to several times later and described on page 136, calculated both with the actual blank and with a constant blank equivalent to to 1·1 cc. $\frac{N}{10}$ Ammonia :—

TABLE I.

Soil.	Acidity calculated with actual blank.	Acidity calculated with constant blank.
Borbhetta Check	1,042	773
„ Lime	1,064	694
„ Small KNO_3	1,288	705
„ „ K_2SO_4	918	593
„ „ Super	958	627
„ Big KNO_3	924	450
„ „ K_2SO_4	1,103	722
„ „ Super	1,176	700

By comparing these figures with those given in Table III it will be seen that by using this constant blank, values much nearer agreement with the Hopkins values are obtained.

A study of other cases, connected with the agreement between the Hopkins and the modified Albert method is interesting. Thus in the case of Tocklai soil quoted above the use of the constant blank gives an acidity of 196 while the Hopkins method gives a value of 190.

In other cases, however, where the soil is decidedly acid the Albert modified and Hopkins methods gave :—

Soil.	Albert method.	Hopkins method.
Borbhetta Check Plot	773	862
Toklai Check Lime	963	812
Binnakandy peat soil	2,296	1,694

By considering the actual blank given by the soil itself, the discrepancy is still greater.

Duplication of results by the Albert method is very difficult and in this respect the Hopkins method is preferable.

As an indication of some of the factors involved in the modified Albert method the following table offers many suggestions.

Although in the acidity determination baryta is used the action with lime shown below is probably similar for caustic soda, lime and baryta all give the same acidity results :—

TABLE II.

Showing the Fixation of CaO from $Ca(OH)_2$ and Liberation of Bases per 100 grams soil.

	Borbhetta Soil.	Gutoonga Soil.	Numaligarh Soil.
Lime water gms. CaO per litre.	1·205	1·209	1·229
SiO_2 ...	0·010 gms.	0·020 gms.	0·017 gms.
Al_2O_3 ...	0·027 „	0·023 „	0·018 „
Fe_2O_3 ...	nil.	nil.	nil.
CaO ...	1·035 „	1·060 „	1·137 „
MgO ...	0·33 „	0·0038 „	0·0015 „
K_2O ...	0·002 „	0·006 „	0·004 „
Lime requirement calculated on titration. ...	4,015	4,119	4,269
Lime requirement calculated on lime fixed ...	1,700	1,490	830
Lime requirement by modified Albert method ...	1,042	560	1,344

It will be noticed that sodium was not estimated.

The amount of alumina passing into solution is astonishing for calcium aluminate is particularly insoluble. Alumina may pass into solution as a silicate rendered soluble through the breaking up of some complex or by the action of an acid body such as HNO_3 on $Al(OH)_3$. Elaborate precautions were taken to exclude carbon dioxide from the experiment, so the loss of alkaline lime is due not to the formation of insoluble carbonate but to the presence of acid bodies.

The discrepancy between the lime requirement calculated on the lime fixed and as estimated by the modified Albert method is due to different conditions. Although in both cases alkaline solutions of approximately the same strength are used, the ratio solution to soil is 10/1 in the former and 4/1 in the latter case.

The lack of co-ordination between the acidities calculated from different sources with different soils is due to fundamental differences in the chemical constitution of the various samples studied.

All evidence resulting from our work points to alumina as being the cause of soil acidity in North-East India, and although it is desirable to interpret, if possible, the meaning of the acidity values given by the Albert method for our soils, since so many results have been accumulated, it is, however, more desirable to estimate directly if possible the cause of the trouble. Most soil methods are too drastic in that they estimate the potential acidity capable of realisation after an indefinite period. The Hopkins method is similarly too drastic but not so drastic as the modified Albert method. A comparison of the two methods is given below :—

Borbhetta soil	... Albert	... 1,042
„ „	... Hopkins	... 860

By experience it was found that 200 parts per million gave the best results.

What the Hopkins method actually estimates is an important question. As Hopkins states, it is a measure of the acid silicates but it is also a measure of the easily exchangeable alumina which, in soils undergoing laterisation, is present chiefly as a hydrated oxide.

Below is a table showing the relationship between the acidity by this method and the quantity of alumina liberated :—

TABLE III.

Soil.	Mgms. Al_2O_3 per 100 gms. soil.	Lime requirement.
Borbhetta Check	30	862
„ Lime	19	350
„ Small KNO_3	18	459
„ „ K_2SO_4	20	582
„ „ Super	11	391
„ Big KNO_3	16	311
„ „ K_2SO_4	16	454
„ „ Super	10	378
„ Magnesia	23	754
„ $CaO+(NH_4)_2SO_4$	16	577
Kharikatia	4	190

It is at once seen that the two quantities are not in agreement. Knight (19) has observed that the liberated alumina is insufficient to account for the acidity developed.

The action of potassium nitrate on the decomposable aluminium compounds in the soil may be represented by the equation.

$$AlX_3 + 3\ KNO_3 = Al\ (NO_3)_3 + 3\ KX$$

Where X represents a particular hydrated silicic or alumino-silicic acid. The aluminium nitrate is then partially hydrolysed as follows :—

$$2\ Al\ (NO_3)_3 + 3\ H_2O = 2\ Al\ (OH)_3 + 6\ HNO_3$$

It is possible that some of the alumina fails to pass through the filter paper. The titration of the extract proceeds until not only the free nitric acid but that originally in combination with the alumina is neutralised. This may be represented as follows :—

$$Al\ (NO_3)_3 + 3\ NaOH = Al\ (OH)_3 + 3\ NaNO_3$$

In this case 1 part $NaOH = 0{\cdot}42$ part Al_2O_3. The table below shows the alumina found in the extract and the acidity of the extract. It will be noted that the alumina found does not account for the whole of the acidity developed, that is, supposing that the equations above represent what is really happening.

TABLE IV.

Soil.	Mgms. Al_2O_3 per 100 gms. soil.	Mgms. NaOH to neut. acidity per 100 gms. soil.	Mgr. Al_2O_3 equivalent to NaOH used.
Borbhetta Check	30	49	52
,, Lime	19	20	21
,, Small KNO_3 ...	18	26	28
,, ,, K_2SO_4 ...	20	33	35
,, ,, Super ...	11	19	20
,, Big KNO_3 ...	16	18	19
,, ,, K_2SO_4 ...	16	26	28
,, ,, Super ...	10	22	27
,, Magnesia	23	43	46
,, $CaO + (NH_4)_2SO_4$ ...	16	33	35
Kharikatia Soil	4	9	10

Knight (19) has also shown that normal KCl, KNO_3, $NaNO_3$, NaCl and $CaCl_2$ give the same acidity results by the Hopkins method. However it has been noticed that Borbhetta soil gives a result of 610 with N/1 K_2SO_4 compared with 872 and 862 with N/1 KCl and KNO_3 respectively. In all three cases the quantity of alumina liberated was different with Binnakandy —a peat soil—with quite a different type of acidity a great variation is observed. The results are shown below:—

TABLE V.

Soil.	Solution employed.	Acidity.	Mgms. Al_2O_3 liberated.
Borbhetta	N/1 K_2SO_4	610	12
	N/1 KCl	876	24
	N/1 KNO_3	862	30
Binnakandy	N/1 K_2SO_4	2,527	61
	N/1 KCl	2,027	52
	N/1 KNO_3	1,694	138

With the Binnakandy sample much iron was liberated along with the alumina, especially with the KNO_3 experiment, and both bases were weighed together.

This side of the question is being further investigated.

Experiments are being carried out to determine the exact content of the extract from these soils and this should do much to clear up the question. In the meantime the Hopkins method is accepted as the one most capable of the well-known methods of expressing soil acidity in North-East India.

The results given by alkaline soils by the modified Albert and the Hopkins methods are interesting. With the Albert method the blank is naturally very great but the soil even when it is strongly alkaline and has received as much as 16,000 lbs. lime per acre is still capable of fixing baryta so that the net result is an acidity. The alkalinity of the check plot—best perhaps described as basicity—as shown by the Albert method is obtained from the blank experiment and is a measure of the ammonia liberated by the soil from ammonium chloride.

With the Hopkins method, the alkalinities represent the result of the reaction :—

$$2\ KNO_3 + CaCO_3 = K_2CO_3 + Ca\ (NO_3)_2$$

which will not proceed far. The values are shown below in Table VI :—

TABLE VI.

At Tocklai, plots received different quantities lime and limestone and gave the following acidities and alkalinities after an interval of 5 years.

Plot.	Lime added parts per million*	Hopkins method.			Albert method.	
		Acidity.	Alka-linity.	Mgms. Al_2O_3 per 100 gms. soil.	Acidity.	Alka-linity.
Check	......	812	...	29	1,254	146
4,000 lbs. limestone	750	47	...	4	900	400
12,000 „ „	2,240	20	...	2	680	650
24,000 „ „	4,480	...	21	trace	640	1,220
32,000 „ „	5,970	...	42	„	750	2,800
8,000 „ lime	2,670	...	14	„	720	1,400
16,000 „ „	5,330	...	70	„	720	4,400

* Calculated on top 9″ soil=3,000,000 lbs.

ACIDITY, ALUMINA AND FERTILITY.

Alumina as the aluminium ion has been shown to be toxic to tea (18). Leguminosae grow badly in Assam, but with liming they grow well as has been shown by Meggitt (17).

At Borbhetta a series of experiments were carried out by Andrews (20), Cooper (21) and Wiles (22) in order to observe the effects of different manures. The ground at Borbhetta is old grazing land which turns very badly and for the first few years is extremely infertile. The plots were first limed and three weeks later the other manures were added. Since 1918 no further manuring has been carried out. The crop was a six-week one-Cowpeas *(Vigna Catiang)*. The season 1921 was so bad for green crops that nine weeks elapsed before the crop was sufficiently advanced for gathering.

The Table below shows the percentage increase over the check plots :—

TABLE VII.

Showing the effect of Manures on Cowpeas Crop at Borbhetta manured in 1918.

Figures show increase per cent. over Check Plots.

Manuring.	Increase percent over check plots.			
	1918.	1919.	1920.	1921.
Lime only (equivalent to 800 lbs. slaked lime)	−14	44	105	1,100
Lime (equiv. to 800 lbs. slaked lime) Sulphate of ammonia 150 lbs. ...	9	62	110	1,466
Carbonate of magnesia 900 lbs. Sulphate of ammonia 150 lbs. ...	18	71	95	726
Lime (equiv. to 800 lbs. slaked lime) Nitrate of potash 50 lbs. ...	−5	57	109	1,230
Lime (equiv. to 800 lbs. slaked lime) Sulphate of ammonia 150 lbs. Sulphate of potash 75 lbs. ...	14	100	140	1,353
Lime (equiv. to 800 lbs. slaked lime) Sulphate of ammonia 150 lbs. Superphosphate 150 lbs. ...	49	81	153	1,053
Lime (equiv. to 800 lbs. slaked lime) NITRATE OF POTASH 2,500 lbs. ...	−7	210	219	1,917
Lime (equiv. to 800 lbs. slaked lime) Sulphate of ammonia 150 lbs. SULPHATE OF POTASH 8,000 lbs. ...	−85	121	266	2,105
Lime (equiv. to 800 lbs. slaked lime) Sulphate of ammonia 150 lbs. SUPERPHOSPHATE 8,200 lbs. ...	41	224	267	1,804

It is easy to interpret these results if the theory of toxic alumina be accepted. The outstanding crops are given by the big potassium nitrate and sulphate and the big superphosphate application. The preliminary depression shown by potash should be noticed. Superphosphate, no doubt, fixes the alumina and the extra heavy dose does no more in the first year than the light dose. In the following years, however, it goes ahead and its value, not only as a remover of toxins but as a food, is felt. Both the potash additions render the alumina soluble and it is then leached

out. This is in accordance with the experience of Mirasol (23). During the period preceding the leaching out of the aluminum salt, however, a depression is felt.

After three years the effect of lime is seen to be relatively as great as most of the other manures. Here precipitation of alumina as calcium aluminate and perhaps partly as the hydroxide has been brought about. The preliminary depression often observed in North-East India, especially with clay soils, is, we believe, due to liberation of small quantities of alumina.

The extraordinary increase over the check plot in 1921 is due partly to weather conditions. Throughout the growing period the soil was extremely wet and the moisture content stayed in the neighbourhood of 20% whereas the optimum is about 14%. This merely illustrates the theory which is being developed.

Now if a soil acidity method is to be of much use it should give a measure of soil fertility, but since acidity is only a factor, although an important one, in soil fertility there will of course not be absolute agreement between the two.

Taking the crop values in Table VII above as a measure of fertility it is instructive to compare the acidities (estimated in 1921) as given by the modified Albert and the Hopkins methods.

TABLE VIII.

Showing the Acidities of the Cowpeas Plots at Borbhetta estimated by the Hopkins and Albert Methods.

Plots.		Hopkins.	Albert.
Borbhetta	Check	862	1,042
,,	Magnesia	754	......
,,	Lime & $(NH_4)_2SO_4$	577	......
,,	Lime	350	1,064
,,	Small KNO_3	459	1,288
,,	,, K_2SO_4	582	918
,,	,, Super	591	958
,,	Big KNO_3	311	924
,,	,, K_2SO_4	454	1,103
,,	,, Super	378	1,176

The superiority of the Hopkins method as a measure of fertility in North-East India is clearly demonstrated.

The question of alumina after it has been rendered non-toxic is one of great economic importance. With potash it is removed from the soils as has been shown by Mirasol (23) who claims that in some cases 59 % of the alumina is leached out. With superphosphate and lime, however, the alumina remains and the further addition of strong acids may liberate it with disastrous effect on the crop. Reference to Table III, however, shows that in the case of superphosphate it is very firmly fixed and reference to Table VI shows that lime is similarly fixed. Ordinary manurial treatment appears to be unlikely to liberate alumina so locked up.

Soil acidity in Assam increases with the rainfall. Thus in the Doom Dooma district at the head of the Brahmaputra Valley where the rainfall is 112 inches the lime requirement (Albert) for light soils is 2,000 to 2,500. Lower down the Valley at Sibsagar where the rainfall is 90 inches, the acidity for similar soils is 1,500 to 2,000. Still further down at Jorhat where the rainfall is 80 inches the acidity varies from 1,000 to 1,500. The higher rainfall leads to a greater degree of hydration of alumina in its various forms and to a greater ease of solution.

Drainage also affects acidity and hence fertility although no specific figures are at hand White (24) may be quoted. His experience shows that the lime requirement is greater in badly than in well-drained soils.

The effect of cultivation on soil acidity is well marked all over the tea districts. Twenty years of incorrect cultivation not only increases the soluble iron and alumina but forms a pan, above the water level, rich in alumina and iron. Mann (25) gives many instances of increases in iron and alumina in soils after cultivation and also of increases in the sub-soil. In virgin soil under jungle or grass the tilth will be perfect and any decrease in alumina in the soil after cultivation will probably be due to improved drainage.

The cycle appears to go thus—

$$\left.\begin{array}{l}\text{lack of lime and magnesia in soil}\\ \text{heavy rainfall}\\ \text{incorrect cultivation}\\ \text{bad drainage}\end{array}\right\} \text{— Soil acidity.}$$

Soil acidity.
|
Alumina.
|
Infertility.

The methods for overcoming this infertility are indicated by the Borbhetta experiments detailed above. The acid manure, superphosphate, has the greatest effect and here we may refer to the experience of Hartwell and Pember (26) who noticed that "acid" had the same effect on barley as on oats, but acid soil extracts which were afterwards shown to contain alumina affected them differently. The effect of the free sulphuric acid in superphosphate would partly be to bring into solution alumina as sulphate which would be fixed as phosphate.

It has also been observed (27) that Lucerne will not grow in clay soils and it has been suggested that roots are unable to penetrate a stiff soil. It is much more likely that such a plant finds the percentage of soluble alumina too great in such a medium.

Much of the blight suffered by tea is made possible by the soil acidity of North-East India. Andrews (28) has noticed that on light soils potash manures free the tea bush from mosquito blight (*Helopeltis Theivora*). On clay soils, however, the effect is either negligible or such that the blight is increased. In one case the alumina is easily leached out and in the other it remains for a long time to do harm to the bush.

It should also be observed that in the tea districts, potassium nitrate has been almost wholly abandoned in favour of sodium nitrate as a nitrogenous manure, while calcium nitrate has been employed, but in nearly all cases with unsatisfactory results. The crop has often been depressed in the year of application of the manure.

A detailed study of the soils of the Brahmaputra Valley shows that the process of laterisation is slowly taking place everywhere with a corresponding stiffening of the soil. The climatic conditions favour this process. As the soluble silica is removed from the iron and aluminum silicates, the oxides of these metals are left in forms more or less hydrated. The percentage of soluble iron and alumina thus forms a measure of the degree of laterisation. The Hopkins method of measuring soil acidity also estimates the amount of weathering of a soil since it estimates the amount of easily soluble alumina.

Toxic Alumina.

In conclusion, the question of the manner in which alumina is toxic may be considered, for this, together with a method for determining soil acidity which is in the main due to alumina, indicates the future line of work.

Truog (29) in a discursive article on the relation of soil acidity to the growth of plants comes to the conclusion that the main specific injury of soil acidity is that it prevents plants, especially those with high lime requirements and relatively weak feeding powers, from getting the lime from the soil at a sufficiently rapid rate to meet their needs. In the tea districts, however, the crop responds not only to lime but equally well to other free bases. Alumina, resulting from a lack of strong bases in the soil, is undoubtedly the cause of infertility.

Gainey (30) has shown that azotobater work best in alkaline soils and Bear (31) working on soils with acidities up to 4,000 (Veitch) came to the conclusion that plants able to utilize nitrogen as ammonia need not suffer in acid soils with a lime requirement no higher than that mentioned. Plants dependent on nitrate, however, will suffer. He also noted that acid phosphates aided the fixation of nitrogen and that small additions of lime were more effective than larger ones.

These observations correspond with field experience in North-East India.

Carpenter and Bose (32) working on nitrate and ammonia formation in soils from Brahmaputra Valley have shown that whilst the formation of nitrates is increased largely by the addition of lime to the soil, ammonia formation is practically unchanged.

All these facts point to the toxic action of alumina as being not merely directly on the plant but through the soil micro-organisms It must however be remembered that aluminium ion of concentration 1 part per million of soil has been shown to be toxic to the tea plant (18).

Conclusions.

1. Soil acidity in North-East India is chiefly due to the presence of soluble ionic salts of aluminium the amount of which is largely influenced by the quantity of aluminium hydroxide present in the soil.

2. The acidity of the soils under consideration is best determined by a method which estimates the amount of alumina capable of easily entering the soil solution. Such a method is that suggested by Hopkins.

3. Lime requirement methods as at present employed are unsatisfactory for giving a true representation of the soil acidity.

4. Acidity due to aluminium may be overcome by potash, which removes it from the soil or by lime and superphosphate both of which fix it in the soil.

5. The degree of chemical hydration of the soil colloids some of which are aluminium bodies affects soil acidity. In this manner rainfall, cultivation and drainage all *influence soil acidity.*

6. Potential acidity is largely measured by the amount of easily soluble alumina.

7. Acidity is a factor, of an inverse order, of soil fertility.

8. Aluminium may be toxic by direct action on the plant or by its action on the micro-organisms in the soil or both.

9. Probably all types of acidity occur in acid soils to a lesser or greater degree. The type of acidity connected with aluminium hydroxide undoubtedly prevails in the tropics or where laterisation of silicious aluminium minerals is taking place.

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CULTIVATION AND WATER CONTENT OF SOILS.

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It is generally recognised that the chief physical properties of a soil affecting plant growth are moisture, aeration, temperature, texture and tilth. The moisture content is affected by drainage in the rainy season and by keeping a loose surface free from weeds in the dry season. Since the free air space in a soil is that space not occupied by water it follows that aeration is dependent on moisture control. The factor most under control is tilth.

Tilth.

After land has been beaten down by rain its volume weight is increased from the well tilled condition brought about through cultivation. This difference is strikingly seen when the height of an area which has been hoed or ploughed is compared with that of the land-side. This loose condition is called tilth and results from the formation of complex crumbs between which there are large air spaces. In nature tillage is kept by means of a network of roots and the upper surface of the soil is protected from beating rain by a layer of fallen leaves.

In order to understand the true meaning of tilth it is necessary to consider the ultimate mechanical constitution of the soil. The sand, silt and clay particles if they were all separate would form with many soils, especially the heavier ones, a solid mass with practically no free air space. Soils which have been incorrectly manured and cultivated get into this state and it is often a matter of great time and expense before the soil particles can be aggregated sufficiently to form the "crumb" by which good tilth can be recognised.

The Optimum Water Content.

Experienced agriculturists can tell when the soil is in the optimum condition for cultivation. The soil at the optimum water content contains just enough moisture to cover all the particles

and aggregates so that they float in a film of water which acts as a lubricant. At this stage the penetration of the soil is most easy both for plant roots and for agricultural implements. As the soil becomes drier, the film of moisture on the particles becomes thinner and in place of cohesion we get a certain amount of cementation taking place. Finally when the soil is quite dry we get a hard mass which gives rise to solid clods when cultivated.

At the optimum water content the soil occupies its greatest volume and as more water is added it shrinks and in doing so offers a greater resistence to penetration.

Cultivation and Water Content of the Soil.

At the end of the rains when the top of the soil has been beaten into a hard cake it is usual to put in a deep hoe and to leave a mulch. This loose layer of soil cuts off the real soil moisture from the air and so effectively stops evaporation that even after a long drought the soil underneath is quite moist. Observations at Tocklai have shown that by this method the moisture remains at about the optimum throughout the dry season, for ordinary drainage is apparently only capable of removing water in excess of the optimum.

If cultivation is carried on whilst the soil is wetter than the optimum the aggregates are broken down in a manner similar to that employed in brick making or in puddling the bottom of tank. If this goes on for some time tilth is destroyed and the crop suffers. After some years, the finer particles which have been released from their aggregates are washed down to the water table and an impermeable pan forms which keep the water from flowing away in the rains and prevents water from from rising in the dry season.

Cultivation at the optimum water content does not involve these complications.

Determination of the optimum.

The question may now be asked—How can the optimum be determined? At Tocklai, the soil has often turned beautifully under the hoe but analysis has shown the state to be far above the optimum and undoubtedly tilth has been destroyed. A simple

field method has been devised whereby the optimum may be determined.

Method.

Take a piled-up double handful of soil ($1\frac{1}{2} - 2$ lbs.) and place in a bottle of about 5″ diam. and $6\frac{1}{2}$″ depth. A wide-mouthed stoppered bottle which may be purchased in the bazaar is convenient for this purpose.

A fair average sample from just below the mulch to a depth of six inches should be shaken with a rotary motion in the bottle for about 45 seconds or a minute.

In collecting the sample care should be taken not to allow any dry lumps of soil which occur in the mulch to be mixed with the true, moist soil, otherwise these lumps are liable, in the shaking, to become coated with a layer of moist soil and to resemble puddled globules.

The result of this shaking is to form the soil into balls varying in size according to the water content. When a soil is very wet the whole mass of soil can be shaken into one ball. When the soil is far above the optimum the sides of the bottle became smeared with a sticky mass which is quite distinct from the friable soil which in a drier state sticks to the bottle. Soil at the optimum also forms into balls if it is shaken long enough, but these aggregates have not the sticky, wet look nor the putty-like feel and adhesiveness which occurs with wetter samples.

After a few experiments on the lines described above the optimum condition can be recognised by working the soil on the palm of the hand. Below are illustrations showing the result of shaking soils at different moisture contents. A stage between the optimum and 15·92 per cent. moisture was obtained containing 14·44 per cent. moisture, but the photograph failed to distinguish it from the 15·92 per cent and 13·63 per cent. samples.

Good Cultivation.

Good cultivation does not necessarily mean much cultivation. At Tocklai the soil is analysed every day for moisture content and the optimum value of the soil has been determined by accurate methods. During April of this year (1921) when 14 inches of rain fell on 22 days, the soil

was never in a fit state for cultivation. In May on six days only could cultivation be carried on. The whole of June was wet and thence onwards the optimum state was only occasionally reached during the rains. At times grass and weeds became so thick that a hoe had to be put in but the gain was doubtful. A better process is to fork round the bushes.

The history of cultivation in the tea gardens of North-East India throws an interesting light on some of the present day problems of the tea planter. With the great influx of coolies about 15 years ago a great increase in the number of rounds of hoeing followed. This in turn pushed up the crop, but some years later the effect of loss of tilth and pan formation became apparent in the susceptibility of the bush to blight attack. Gardens which have always been short of labour and which in the rainy season have been forced to put every cooly on to plucking and to abandon cultivation till the cold season have remained comparatively free from blight.

Illustrations showing the effect of working a soil under different moisture conditions.
The soil sample is a light sandy loam taken from Tocklai.

A PRELIMINARY PEST CALENDAR FOR THE TEA DISTRICTS OF NORTH-EAST INDIA

BY

E. A. ANDREWS, B.A.

Shikar plays a great part in the lives of many tea planters, and one has often felt, while admiring the intimate acquaintance of its devotees with the life history and habits of birds and animals which afford sport to the shikari, that if the same enthusiasm could be applied to the study of the insect pests of tea the enthusiast might possibly become as expert in insect control as in shikar. One of the first essentials for success in shikar is a thorough knowledge of what the bird or beast may be expected to do, and when it may be expected to do it. Similarly, the control of insect pests can only be carried out satisfactorily and economically by one who is in a position to anticipate the movements of the insects he proposes to deal with.

We publish below a preliminary pest calendar for the tea districts of North-East India, showing, month by month, the stages in which some of the principal pests of tea may be expected to occur, which, we hope, will assist planters to anticipate the movements of our insect foes, and thus place themselves at an advantage when control measures are necessary.

This calendar is by no means complete, and will probably be found not altogether accurate. The detailed life histories of many of the pests of tea are not yet worked out, and where this has been done the extensive overlapping of successive generations very often makes it difficult to decide when the maximum number of individuals exist in any particular stage. It has been compiled, however, after a careful comparison of the information afforded by breeding notes made at Kanny Koory and Tocklai, by reports on tea pests which have issued from the department during the past ten years,

by the monthly entomological reports received from tea gardens during the last five years, and by a number of records of the occurrence of the pests running into thousands, and every care has been taken to make the calendar as accurate as possible.

Interested planters will probably note any discrepancies which they may observe, and record the same on their monthly entomological report forms, which, with the observations continually being recorded by the department, will render possible the publication of corrected calendars from time to time.

The calendar has particular reference to the districts of middle Assam. In Cachar and Sylhet dates may be a little earlier, in the Duars and Darjeeling a little later.

A note on the control measures which are of value against the different pests is given for each month, which should increase the value of the calendar.

JANUARY.

Crickets ...	These insects are now present in the young stages, and may be damaging early nurseries or heavy pruned tea.
Orange beetle ...	To be seen in small numbers.
Cockchafer (kumli kera).	Now present in the soil as grubs.
Wireworm ...	To be found in the soil in nurseries, and generally noticed when the *kumli kera* is being looked for.
Red slug ...	Now to be found in the soil in the chrysalis stage.
Faggot worms ...	A large proportion of the faggots to be found in the tea at this time contain eggs which are now beginning to hatch out.
Red borer ...	The caterpillars of this pest are to be found inside the stems of the bushes.
Nettle grub ...	The tea-seed-like cocoons of this pest are present in the soil among the tea bushes.

Gelatine grub ...	The cocoons of this pest, which likewise bear a considerable resemblance to tea seeds, are to be found attached to the branches and twigs of the bushes, and occasionally in the soil.
Looper ...	This pest is now in the soil in the chrysalis form.
Bark-eating borers	The caterpillars are now active in the tea.
Sandwich caterpillar.	The pest is now in the soil in chrysalis form.
Tea mosquito ...	Present in very small numbers in all stages.
Green-fly ...	Present in small numbers in all stages.
Scale insects ...	These are to be found in the tea at most periods of the year, but this is the best time to deal with them.
Thrips ...	The common thrips is present in the soil in the pupal condition, the black thrips is in the pupal condition among the mosses and lichens and other rubbish in the bushes.
Termites ...	These insects are now active above ground.
Red spider ...	Mainly wintering in the egg or adult condition in corners and crevices on the bushes and in the ground.

Control Measures.

Forking, kurpying, and thullying keeps down termites, and enormous numbers of chrysalids of the caterpillar pests can be collected at the same time. Treatment of heavy pruned tea with soda washes, and of light pruned tea with strong lime-sulphur, is of immense value for scale insects, for removing moss and lichen, and with them thrips, destroying eggs of tea mosquito, and hibernating red spider, and for interfering with bark-eating borers. The burning or burying of prunings destroys large numbers of most pests. Collection of faggot worms at this period results in the destruction of large numbers of eggs.

FEBRUARY.

Crickets ...	Are present in the young stages.
Orange beetle ...	To be seen in small numbers.
Cockchafer ...	Present in the soil as grubs.
Wireworm ...	Noticeable in the soil in nurseries.
Bunch caterpillars	Begin to appear.
Red slug ...	Present as chrysalids in the soil. Moths are beginning to emerge.
Red borer ...	Present in the tea shoots in the caterpillar stage. Almost full grown.
Nettle grub ...	Present in the soil in the chrysalis stage.
Gelatine grub ...	Tea-seed-like cocoons to be found on the bushes and occasionally in the soil.
Looper ...	Present in the soil as chrysalides.
Bark-eating borers	The caterpillars are at this time active in the tea.
Sandwich caterpillar.	Caterpillars begin to emerge. Pupae still to be found in the soil.
Tea mosquito ...	Present in very small numbers in all stages.
Green-fly ...	Present in small numbers in all stages.
Scale insects ...	Those which affect the stems are still active.
Thrips ...	The common thrips is present in the soil in the pupal stage, while the black thrips is at the same stage and hidden in lichens and moss on the branches of the bushes.
Termites ...	Active above ground.
Red spider ...	Still hibernating.

CONTROL MEASURES.

Kurpying, thullying, and forking, with collection of cocoons and chrysalids, should still proceed. Late pruned tea should be treated with soda washes if heavy pruned, or lime-sulphur if light pruned. Early pruned tea will receive a check if treated with soda

washes now, but lime-sulphur may be safely used at twice the usual summer strength. This is the time to commence organised collection of pests by means of pest gangs. Bunch caterpillar can be dealt with before it does much damage, sandwich caterpillars may be destroyed by crushing the "sandwiches" between the finger and thumb as recommended by Antram, and systematic searching of the new growth on areas known to be affected by the mosquito will result in the destruction of a great proportion of the young forms.

MARCH.

Crickets ...	Are still present in the young stages.
Orange beetle ...	Begins to increase in numbers.
Cockchafers ...	Are still present in the soil as grubs, but the major proportion have reached the pupal stage, and adults are beginning to appear.
Wireworms ...	Are still noticeable in the soil in nurseries.
Bunch caterpillar .	The familiar clusters of these insects begin to show up in the tea.
Lobster caterpillar	Appear, and attain the pupal stage.
Red slug ...	A certain number of pupae are still in the soil, and caterpillars are now present in the tea.
Red borer ...	The caterpillars of this pest are now full-grown, and are beginning to enter upon the pupal stage.
Nettle grub ...	The moths of this insect are now beginning to emerge.
Gelatine grub ...	Moths are now beginning to appear.
Looper ...	The moths of this insect emerge this month and deposition of eggs proceeds.
Bark-eating borers	The caterpillars become full grown, and some individuals reach the chrysalis stage by the end of the month.

Sandwich caterpillar.	Caterpillars may now be present in serious numbers. Early individuals enter the chrysalis stage, and a few moths appear.
Tea tortrix ...	The caterpillars of this moth show up in the tea.
Tea leaf roller ...	The work of these caterpillars becomes noticeable.
Tea mosquito ...	Present in small numbers in all stages.
Green-fly ...	Present in small numbers in all stages.
Tea aphis ...	This pest now appears on the young growth and in nurseries.
Scale insects ...	Many of these are now hatching from the eggs.
Thrips ...	Still in the pupal stage.
Termites ...	Still active in the bushes.
Red spider ...	Begins to appear.

CONTROL MEASURES.

Kurpying, thullying, and forking should still proceed, and chrysalids and cocoons be collected. Bunch and sandwich caterpillars and tortrix and leaf roller, should be destroyed by hand if serious. Systematic searching for tea mosquito on the new growth should continue, and affected bushes be soaked with lime-sulphur solution of normal strength. This solution may also be used, where necessary, for red spider and tea aphis.

APRIL.

Crickets ...	Are still in the young stages, though more than half grown. In this month the damage done generally becomes so serious as to attract notice.
Orange beetle ..	This insect is still increasing in numbers. The drooping shoots, formed as a result of the attack, begin to attain such numbers as to be noticeable.

Duars leaf-eating beetle.	This beetle may be expected to appear this month, more especially in the Duars, where it skeletonises the leaves of a few bushes, persists for about three weeks, and then disappears. In Darjeeling it may appear as late as July.
Green beetle ...	This insect now appears in the tea.
Cockchafer ...	The adult beetles are now emerging, but damage by the grubs has been recorded at this time also.
Wireworms ...	May be noticed in the soil in nurseries.
Bunch caterpillar .	These caterpillars are generally less prevalent this month, the majority of the individuals being in the pupal and adult stages.
Lobster caterpillar	Present in the pupal and adult stages.
Red slug ...	The caterpillars are present in the tea, and begin to pupate in the soil.
Faggot worms ...	The young caterpillars begin to appear.
Red borer ...	Present in the pupal condition. Moths begin to appear.
Nettle grub ...	Moths are emerging from the cocoons, and deposition of eggs is proceeding.
Gelatine grub ...	Moths are emerging from the cocoons, and deposition of eggs is proceeding.
Looper ...	The emergence of moths, and egg-laying, continue. Caterpillars begin to appear.
Bark-eating borers	Chrysalids continue to form during the early part of the month, and moths begin to emerge.
Sandwich caterpillar.	Pupae are to be found in the soil, the moths are about in considerable numbers, and the caterpillars begin to appear again.
Tea tortrix ...	This insect reaches the pupal and adult stages this month.

Tea leaf roller ... Reaches the adult stage this month.

Tea mosquito ... Present in all stages.

Green-fly ... Present in all stages. The leaf begins to take on the characteristic green fly appearance.

Tea aphis ... Active on the young growth and in nurseries.

Scale insects ... Which attack the leaf begin to appear.

Thrips ... Begin to appear on the bushes this month.

Termites ... Still active above ground, but with April rain their activity diminishes somewhat.

Red spider ... Active on the bushes.

Pink mite ... Active on the bushes.

Control Measures.

April is an important month from the point of view of insect control. Crickets now demand attention, and those who cut down the heavy pruned tea early reap the benefit. Pouring water down the hole generally brings the insect to the mouth of the hole very quickly, and a kurpy pushed in slantwise below him completes his capture. Kerosene emulsion, diluted 1 in 40, may be substituted, and has the advantage that it kills the insects which obstinately refuse to emerge. Poisoned baits may be spread in nurseries. This is the time to collect faggot worms. The young insects have emerged from the parent case and are feeding on the bush. As they have not yet had time to spread far the damage, which is considerable and easily seen, is confined to a few bushes, and the rapid collection of large numbers is a comparatively easy matter. Bark-eating borers are in the chrysalis stage, and as the chrysalids are situated half in and half out of the holes efficient collection is an easy matter as compared with other times. Bunch caterpillars, forming their cocoons, as they do, on clods at the surface of the soil, are destroyed in large numbers by the hoe, and red slug is entering the danger zone by going to the soil to pupate. Systematic collection of tea mosquito, and soaking of affected bushes with lime-sulphur, can be continued effectively, and red spider and pink

mite may be dealt with by spraying with lime-sulphur. Thullying may be done wherever possible to keep down termites.

MAY.

Crickets ...	Have not yet attained maturity, but the young forms are increasing in size, and damage is generally most serious this month.
Orange beetle ...	Is usually present in its greatest numbers.
Green beetle ...	Attains its maximum numbers.
Cockchafer ...	Adult beetles are still emerging, and grubs are hatching from eggs laid by the early individuals.
Wireworms ...	Are still active in the soil.
Bunch caterpillar	The caterpillars begin to appear again.
Lobster caterpillar	The adult moths are depositing eggs.
Red slug ...	The majority of the individuals are in the adult stage.
Faggot worm ...	The depredations of these insects are still noticeable here and there in the tea.
Red borer ...	Moths continue to emerge. Eggs are being laid.
Nettle grub ...	Young caterpillars are to be found in the tea. Moths are still about.
Gelatine grub ...	Young caterpillars are to be found in the tea. Moths are still about.
Looper ...	Caterpillars are active in the tea. Early individuals are beginning to form chrysalides in the soil.
Bark-eating borers	Are present mostly as moths and the deposition of eggs is proceeding.
Sandwich caterpillar.	Is active in the tea, and pupae are forming in the soil.

Tea mosquito ... Is present in all stages. In some places it may be already having a serious effect on the bushes.

Green-fly ... Is present in all stages, and its effects are noticeable both in the size and quality of the flush.

Tea aphis ... Is still active on the young growth and in nurseries, though the bushes are beginning to throw it off.

Scale insects ... Are active both on the branches and leaves, and more particularly noticeable on the latter, but are not greatly in evidence.

Thrips ... Is active, and present on the bushes in larval and adult stages.

Termites ... Are still active above ground, though not often noticed on account of the foliage on the bushes.

Red spider ... Is active, and present in all stages.

Pink mite ... Is active, and present in all stages.

CONTROL MEASURES.

The measures taken during the previous month against crickets may be continued if necessary. The treatment of tea mosquito, red spider, and pink mite should be continued as in April, if the pest be still serious. Thrips may be sprayed with Insecticide Xex green if obtainable, or, failing that, with lime-sulphur. A last round of thullying, before the rains break, will be of great service against termites.

JUNE.

Crickets ... This month these insects begin to reach the adult stage, and the damage done begins to decrease. There are still a large proportion of young forms about.

Orange beetle ...	These insects are decreasing in number, and the damage done is becoming less noticeable.
Green beetle ...	The number of these insects is decreasing.
Cockchafer ...	Young larval grubs are present in the soil.
Wireworms ...	May be still active.
Bunch caterpillar	Present in all stages.
Lobster caterpillar	Are to be found in the tea. May reach the pupal stage.
Red slug ...	Most of the individuals are in the adult stage. Caterpillars are beginning to reappear.
Faggot worm ...	The caterpillars have by this time spread to greater distances into the tea, which is likewise now well covered with foliage, and though present are not readily noticed.
Red borer ...	Young caterpillars are at work in the shoots, but the damage is not yet noticeable.
Nettle grub ...	The presence of the caterpillars in the tea now begins to become noticeable.
Gelatine grub ...	Present in the tea in the caterpillar stage.
Looper ...	The last of the caterpillars pupate, and the emergence of the moths commences.
Bark-eating borers	Caterpillars begin to appear, and damage to the bushes commences.
Sandwich caterpillar.	Present in the soil in the chrysalis stage. Moths appear.
Tea mosquito ...	Present in all stages. The attack may by now be serious.
Green-fly ...	Present in all stages. June is generally a green-fly month.
Tea aphis ...	May still be present.
Scale insects ...	Are active, more especially in the hills.

Thrips ... Is active on the bushes in larval and adult stages. The migration to the soil, where the rains will be spent in the pupal state, commences.

Termites ... The activities of these insects above ground begin to lessen.

Red spider ... The damage done by this pest may begin to decrease.

Pink mite ... A decrease in the numbers of this pest begins.

Control Measures.

As soon as Looper caterpillars have disappeared from the tea a hoe may be put into the affected sections, which will kill many pupae. If the bushes can be forked and chrysalids collected so much the better. In the case of a late rains spraying for red spider may still be necessary. If mosquito be now serious the treatment may be discontinued. Where the pest has not yet got the upper hand the treatment should be continued as far as possible. Spraying for Thrips may be necessary.

JULY.

Crickets ... These insects have now practically all become adult, and their depredations have decreased considerably.

Orange beetle ... Present in small numbers only.

Duars leaf-eating beetle. Has been known to occur in Darjeeling during this month.

Green beetle ... Present in small numbers.

Cockchafer ... Present as young grubs in the soil.

Bunch caterpillar These caterpillars now become almost negligible.

Lobster caterpillar This insect may be found in all stages at various times during the month.

Red slug ...	Is present in the tea in the larval condition, and passes into the pupal stage, some individuals attaining maturity by the end of the month.
Faggot worms ...	Present in the caterpillar stage.
Red borer ...	Young caterpillars are present in the shoots but the damage done is as yet unnoticeable.
Nettle grub / *Gelatine grub*	These caterpillars become more noticeable.
Looper ...	The emergence of the moths continues, and the caterpillars re-appear.
Bark-eating borers	Are present on the bushes in the caterpillar stage.
Sandwich caterpillar.	The moths are in evidence, and caterpillars are again appearing.
Tea mosquito ...	Present in all stages. The pest has usually become serious.
Green-fly ...	Present in all stages, but the effect on the bushes is now practically *nil.*
Tea aphis ...	Present, but scarcely noticeable.
Scale insects ...	Present, but not greatly to be noticed except in the hills.
Thrips ...	Almost entirely disappears this month.

Control Measures.

There are no special control methods which have been found of value at this period. The time for effective control has in most cases passed.

AUGUST.

Crickets ...	The most belated of the insects become adult this month, and the depredations of the pest become *nil.*
Orange beetle ...	Present in small numbers only.

Green beetle ...	A few may still be seen.
Cockchafers ...	Present as grubs in the soil.
Lobster caterpillar	May be found in all stages at different times during the month.
Red slug ...	Moths are still appearing during the early part of the month. Larvae begin to appear towards the end of the month.
Red borer ...	The damage done by these caterpillars, which are still at work inside the shoots, begins to show up, and the brown leaves of the dying branches are particularly noticeable in the green tea.
Nettle grub ...	The attack of this caterpillar attains its maximum.
Gelatine grub ...	The attack of this caterpillar attains its maximum.
Looper ...	The caterpillars are active in the tea, and the descent to the soil for pupation commences.
Bark-eating borers	These insects are present on the bushes in the caterpillar stage.
Sandwich caterpillar.	The caterpillars may be present on the tea, and chrysalids are to be found in the soil.
Tea tortrix ...	The caterpillars of this moth often attain sufficient numbers to be noticeable this month. Many pupate. Some attain maturity.
Tea mosquito ...	Present in all stages. Serious by now.
Green-fly ...	Present in all stages, but damage not noticeable.
Scale insects ...	Present, but hardly noticeable except in the hills.
Red spider ...	Temporary indications of the presence of this pest may be observed.

Control Measures.

At this time of year it is a simple matter for a few intelligent men or boys to collect shoots which contain the red borer, as the dead branches are very conspicuous in the tea.

SEPTEMBER.

Crickets ...	All these insects are now in the adult stage. A few of the early individuals commence to lay eggs.
Orange beetle ...	This pest increases in numbers this month.
Cockchafer ...	Grubs are present in the soil.
Red slug ...	Present mostly as larvae. It is at about this period that sporadic attacks often occur. Pupation takes place towards the end of the month, and a few early adults may appear.
Red borer ...	The caterpillars are active in the stems of the bushes, and are rendered noticeable by the conspicuous dead branches here and there.
Nettle grub ...	Caterpillars are still numerous, but begin to decrease, and cocoons have been found as early as September.
Gelatine grub ...	Caterpillars are still numerous.
Looper ...	Pupation continues, and moths begin to appear.
Bark-eating borers	The caterpillars are active in the tea.
Sandwich caterpillar.	Pupae are present in the soil, and moths are again in evidence.
Tea Tortrix ...	Pupae and adults to be found.
Tea mosquito ...	Present in all stages. This is generally the month of maximum severity.
Green-fly ...	Present in all stages, but seldom noticed.
Red spider ...	May recur.

CONTROL MEASURES.

The bushes may often be caused to throw off red spider at this time of year by replacing the light hoe, on the affected section, by a trench hoe, nine inches deep, between the lines.

OCTOBER

Crickets ...	The deposition of eggs continues, and young individuals begin to emerge from the first-laid eggs.
Orange beetle ...	Present in considerable numbers, although the damage done may not be so obvious owing to the greater number of shoots on the bushes.
Cockchafer ...	Present as grubs, but nursery plants are now so high that the damage done is negligible.
Bunch caterpillar	The clusters of this caterpillar may begin to re-appear in the tea.
Red slug ...	Present in the adult stage as moths.
Red borer ...	The dead branches here and there show where the caterpillar is at work in the tea.
Nettle grub ...	Decreasing in numbers.
Gelatine grub ...	Decreasing in numbers.
Looper ...	The emergence of moths continues, and the last brood of caterpillars begins to appear.
Bark-eating borer	These caterpillars are still active in the tea.
Sandwich caterpillar.	Moths are in evidence, and the last brood of caterpillars begins to appear.
Tea mosquito ...	Present in all stages. Serious.
Green-fly ...	Present in all stages.
Thrips ...	There may be signs of this pest at this time.
Termites ...	Begin to re-appear above ground, and their runs may be found as far up as the plucked shoots.
Red spider ...	Is active, and may become noticeable.

Control Measures.

Control measures are of little value now.

NOVEMBER.

Crickets	...	Egg-laying has practically ceased, but the emergence of young individuals continues.
Orange beetle	...	Is beginning to decrease in numbers, but damaged shoots are still noticeable.
Cockchafer	...	Present as grubs in the soil.
Red slug	...	Is now in the caterpillar stage.
Red borer	...	Present in the caterpillar stage, and noticeable by the dead branches here and there.
Nettle grub	...	These caterpillars have mostly entered the chrysalis stage, but may persist.
Gelatine grub	...	Odd specimens may be found here and there, but most have entered the pupae stage.
Looper	...	Present in the caterpillar form. Pupation in the soil for the cold weather begins.
Bark-eating borer		These caterpillars are by now doing extensive damage to the bushes.
Sandwich caterpillar.		Caterpillars still persist. Pupae are present in the soil.
Tea mosquito	...	Present in all stages, but rapidly decreasing in numbers.
Green-fly	...	Present in all stages.
Termites	...	Are becoming increasingly active.

Control Measures.

Control may now be left until pruning and other cold works commence.

DECEMBER.

Crickets ...	Are present in the young stages, but have not as yet spread very far. Tea which has been cut heavily and early may be affected.
Orange beetle ...	Present in small numbers only.
Cockchafer ...	Present as grubs in the soil, which are by now attaining a sufficient size to be a source of danger to young plants.
Faggot worms ...	These will again become noticeable in the tea, and the damage they have been doing throughout the season to the bark of the stems becomes apparent as the bushes are pruned. The caterpillars are seldom now active, and the male faggots are generally empty, while the female faggots contain the eggs.
Red borer ...	Is present in the tea shoots in the larval condition, and the damage done is readily recognised by the hollow branches left in pruning.
Nettle grub ...	Present in the pupal stage in the soil.
Gelatine grub ...	Tea-seed-like cocoons to be found on the branches of the bushes, occasionally in the soil.
Looper ...	The formation of chrysalids in the soil continues, and by the end of the month all are in the pupal stage in the soil.
Bark-eating borer	These caterpillars are doing extensive damage to the bushes, which becomes very obvious as pruning continues.
Sandwich caterpillar.	Pupae are to be found in the soil.
Tea mosquito ...	Present in all stages, but much reduced in number.

Green-fly ... Present in all stages.

Scale insects ... These, and the damage done by them, become especially noticeable as the bushes are pruned.

Termites ... Are active above ground.

Control Measures.

With the commencement of cold weather work a good deal can be done to mitigate subsequent attacks of the various pests. The treatment of the heavy pruned tea with soda washes softens the bark and makes it less suitable for bark-eating borers, removes scale insects, moss, and lichen, and with the latter pupæ of the black thrips, destroys eggs of the tea mosquito and kills hibernating red spider. High pruned tea cannot safely be treated with soda washes, but may be treated with strong lime-sulphur solution, which performs a similar service. Prunings should always be removed from the sphere of action as soon as possible, either by burying or burning. They contain large numbers of pests in various stages, and if left these pests are often able to develop or return to the bushes. Faggot worms are easily collected now, and should be collected assiduously, as each female faggot collected means the destruction of large numbers of eggs. Forking, kurpying, and thullying of the bushes should be a feature of cold weather work. It is of immense value against termites. The women or children who do the thullying should be made to collect all chrysalids they find in the ground. This is far and away the most efficient means of control of the majority of our worst caterpillar pests. During the cold weather, also, the drainage of improperly or inadequately drained areas should be improved as far as possible. This will be found of great value in the fight against pests such as tea-mosquito, red spider, etc.

THE FUNGUS DISEASES OF THE TEA LEAF

BY

A. C. TUNSTALL, B. SC.

AND

S. C. BOSE.

(*Continued from 1920, Part IV, Page 154*).

Copper blight—*Læstadia camelliæ* Cke.
Læstadia Theæ Rac.

Copper blight is so named from the peculiar coppery coloured sheen which forms on the under surfaces of leaves in the early stages of the disease. The leaves so affected usually bend over with the underside outermost. This stage is succeeded by the formation of ill-defined patches of yellowish brown colour. These patches first appear on the upper sides of the leaf. They later on become better defined and darker in colour extending right through the leaf. As the disease progresses minute dots appear scattered about in the centre of the discolourations. The diseased portion of the leaf finally becomes very brittle and frequently cracks.

When examined with a pocket lens both the surfaces of the diseased patches are seen to be studded with minute black dots, irregularly scattered in the neighbourhood of the veins. These black dots are the openings of round cases called pycnidia, in which spores of the kind called pycnospores are produced. A section across such a spot will show under the microscope that the pycnidia are black, more or less spherical receptacles with short beaks, somewhat resembling those of brown blight in external appearance, but differing in their contents. The pycnidia are produced singly or in groups and remain embedded into the leaf tissue with their mouths opening outside. They measure about 98—110 by 113—116·5μ. From the cells of the inner wall of a pycnidium small colourless filaments, known as conidiophores, grow out. These produce colourless one-celled, ovoid spores at their tips. When mature the pycnospores are detached from the cells

of the inner wall of the pycnidia, carrying their conidiophores with them. The pycnospores with the adherent conidiophores are collected in the central cavity of the pycnidium. They measure about 10·85—12 by 6·5—7·5μ. When fully ripe the upper portion of the pycnidial wall with its enveloping leaf tissue disintegrates, leaving a small crater-like depression.

This form of fructification is very common and may be found on diseased leaves throughout the year.

At a later stage when the surface of the spot becomes grey and brittle, the second form of fructification appears as minute black dots similar to but smaller than those mentioned above. On examination of a cross section of such a spot, under the microscope, it will be seen that these black dots are crater-like openings of spherical receptacles known as perithecia. The perithecia are black, more or less spherical shape with very short beaks. They are either scattered or in groups and are immersed in the leaf tissue, with their beaks communicating with the outside. They measure about 99—103·5 by 102—105μ, and contain a large number of club-shaped sacs (asci) each containing 8 spores (in this case called ascospores). The asci are colourless, cylindrical, club-shaped and measure about 52—53 by 12—13μ. The ascospores are colourless, one-celled, broad in the middle and slightly tapering at the ends. When young they contain a large number of refractive granules. They are arranged in two rows within the asci and measure about 13·5—15·5 by 6—7·6μ.

This form of fructification is less common and is only found for a few months (May to August) in the year and then only with difficulty.

Former investigators apparently confused the perithecia of *Glomerella cingulata* (Brown blight) with this stage of this fungus.

The fungus infects the leaf when it is still young. The disease is more common during summer and the rains. It is most frequently observed about the time the second flush appears. It is less in evidence in the cold weather. It is not so common as Brown or Grey blights.

The fungus has been grown in pure culture from both kinds of spores. It grows well in jelly made with either maize meal, glucose or dextrose.

In culture the pycnospores germinate within a day. On germination they give rise to one or two filaments (germ tubes) from one or both the ends. The filaments give rise to lateral branches. The mycelium is at first colourless, becoming deep brown or sooty black with age (in 3—5 days). The filaments are many branched and with many cross walls. The cross walls are darker in colour than the side walls and are very prominent. The pycnidia develop singly or in groups from a mass of mycelium, 7 days after inoculation. They are at first brown, later becoming black, more or less spherical, with a very short beak. The perithecia develop from the same mycelium, 15—20 days after inoculation.

The ascospores germinate in a day in the same manner as the pycnospores. The characters of the mycelium are the same as those observed in mycelium from pycnospores.

Infection of healthy living leaves, both injured and uninjured, with pycnospores took place in from 3—5 days. The pycnidia developed 7 days after inoculation but the perithecia were not observed even after 40 days.

Experiments showed that under ordinary circumstances, *e.g.*, light shade and damp atmosphere the fungus could survive the cold weather when in dead material. But the solitary pycnospores when exposed to similar conditions could live only for 8 days. Exposure to direct sunshine was fatal to both, the former could live for a few months only while the latter succumbed within a day.

The Treatment of the Disease.

Copper blight is not usually sufficiently serious to warrant remedial measures. It is necessary to pluck off all the infected leaves and destroy them. If this plucking is followed immediately by spraying with a fungicidal mixture, *e.g.*, lime sulphur solution, the infection of the young leaves is prevented. A second plucking is frequently necessary a day or two after the spraying but a second application of spray fluid is rarely necessary.

As the disease usually makes its appearance at the end of the first flush, it is generally possible to apply remedial treatment during the dry spell which precedes the heavy rains. When the disease appears in the heavy rains it is very little use applying spray fluids, but if the diseased leaves are plucked off and destroyed there is little danger of serious damage being caused. Sometimes in Darjeeling the progress of the disease is very rapid, but when the disease spreads with such rapidity the diseased leaves generally fall off in a day or two and the young flush comes away unaffected.

NOTES.

Ornamental Trees as Breeding Places for Mosquitoes.—The maintenance of health is of a vital importance in a district such as Assam, and is intimately bound up with the presence or otherwise of mosquitoes. The following table, showing the relative importance of various ornamental and other trees, commonly planted in bungalow compounds, as breeding places for mosquito larvæ, should therefore be of interest. The table, which is taken from an article in the Bulletin of Entomological Research, Vol. XI, Pt. 3, records the number of occasions on which mosquito larvæ were found in rot-holes at the forks or in the end of rotting stumps on the trees.

Common Name.	Botanical Name.	Number of Occasions.
Banyan (4 species) ...	*Ficus thonningii* " *platyphylla* " *populifolia* " *sp.* ...	22
Flamboyant (Gold Mohur) ...	*Poinciana regia*	13
Mango	*Mangifera indica*	6
Pawpaw (Papaya)	*Carica papaya*	5
Woman's Tongue or Egyptian Acacia	*Albizzia lebbek*	4
"Miraculous Berry" (Yoruba agbayun)	*Sideroxylon dulcificum* ..	1
Almond Tree	*Terminalia catappa*	1
Black or Velvet Tamarind ...	*Dialium guineense*	1
Rain Tree	*Enterolobium dulcis*	1
Breadfruit	*Artocarpus incisa*	1
Guava	*Psidium guava*	1
Akee Apple	*Blighia sapida*	1
Queen of Flowers (Ajar) ...	*Lagerstroemia regina* ...	1
(Yoruba-akoko)	*Newbouldia laevis*	1
Cashew	*Anacardium occidentale* ...	1
"	*Sterculia barteri*	1
Alexandrian Laurel	*Calophyllum inophyllum* ...	1
"	*Millettia sanagana*	1
Orange	*Citrus aurantium*	1
Cock-hat Tree (Yoruba-piregun) ...	*Dracaena fragrans*	1
Coconut	*Cocos nucifera*	1
Ornamental Amaryllid ...	*Crinum giganteum*	1
" broad-leaved Screw-pine	*Pandanus pacificus*	1
" striped Screw-pine ...	*Pandanus veitchii*	1

Helopeltis Theivora—Waterh.—The tea mosquito has now made its appearance as a pest in Sumatra, as is evidenced by the following extracts from the Review of Applied Entomology for April 1921.

"GARRETSEN (A. J.): *Helopeltis* op Sumatra [*Helopeltis* in Sumatra].

De Thee, Buitenzorg, *i*, no. 3, September 1920, pp. 75-76.

[Received 7th February 1921.]

The presence of *Helopeltis antonii* and *H. theivora* on the east coast of Sumatra has been definitely established. No loss to the tea crop has resulted as yet, and in advocating great watchfulness and the immediate application of remedial measures in cases of infestation, it is pointed out that the latter does not necessarily make tea-growing unremunerative.

On one estate *H. antonii* occurred mainly on tea beneath *Sesbania aegyptiaca*, and the parts most attacked were those in the shade of these plants, which were themselves infested with this and other bugs. There was no infestation in neighbouring plantations where the tea was grown beneath *Tephrosia*. After felling and burning the *Sesbania* and uprooting the stumps, collection was prosecuted very energetically, and one-and-a-half weeks later the *Helopeltis* had entirely disappeared, a considerable loss being thus prevented.

LEEFMANS (S.): Aanteekeningen over Voedsterplanten var *Helopeltis*.

[Notes on the Food-plants of Helopeltis].—De Thee Buitenzorg, *i*, No. 3, September 1920, pp. 77-78, 2 places.

[Received 7th February 1921].

Adults and eggs of *Helopeltis antonii* var *bradyi* are recorded on *Fuchsia coccinea*, growing at an altitude of approximately 4,800 feet, but no larvæ could be found. Though tea was attacked under laboratory conditions, plants growing about 300 feet away from the *Fuchsia* remained uninfested. Similar observations have led observers to suppose that *Helopeltis* is not a fixed pest of tea,

but the author does not agree, his view being that too little is known about these Capsids, especially as regards the inheritance of morphological and bionomic characters in the various species or races. For this reason research into the genetics of these bugs would be justified, quite as much so as the quest for remedies.

In his garden at Buitenzorg, Dr. Rant found infestation on *Begonai*, *Cuphea micropetala*, and *Wormia suffruticosa*, so that these must be added to the list of foodplants. He also noticed that the upper branches of nangka [*Artocarpus*] were first attacked, and then the lower branches, the insects finally migrating to *Begonia* and the other plants mentioned. This leads the author to think that the reason why *Helopeltis* has not been observed in virgin forests may be the fact that infestation occurs among the tall trees, and that *Helopeltis* only occasionally descends from such elevated situations. An examination of any injury met with when felling in a virgin forest is therefore desirable.

CIRCULAR on *Helopeltis* in Sumatra.—De Thee, Buitenzorg, *i*, No. 3, September 1920, pp. 82-13.

[Received 7th oiaFebruary 1921].

This Circular of the Director of Agriculture, Industry and Commerce for the Dutch East Indies draws attention to the fact that *Helopeltis theivora* and *H. antonii* are now known to occur in Sumatra, and points out the danger attending attempts to conceal the presence of these pests on tea estates."

C. O. P —1,200—10-8-21.

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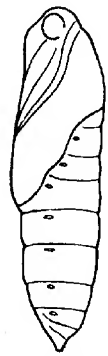
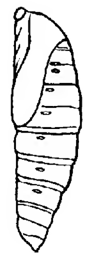
1921.

TYPES OF CHRYSALIDES.

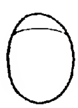
Eupterotid type.
(? Sangatissa).



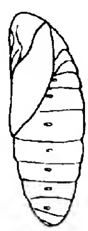
Sphingid type.
(Acherontia).



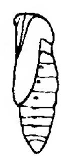
Notodontid type.
(Phalera).



Limacodid type.
(Thosea).

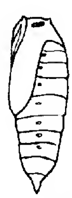


Lasiocampid type.
(Suana).



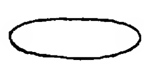
Hypsid type.
(Hypsa).

Noctuid type.
(Arcilasisa).



Geometrid type.
(Biston).

Stenomid type.
(Agriophora).



Cocoon of Parasite.

LITHO, BENGAL ART STUDIO & PRINTING LIMITED.

ON CATERPILLAR CONTROL BY COLLECTION OF CHRYSALIDES

BY

E. A. ANDREWS, B.A.

On many tea estates the collection and destruction of pupae and chrysalids turned up from the soil during the operations of forking and thullying has now become a matter of regular routine, and where this is so an enormous reduction of the damage done has been found to accrue. A typical instance of this is to be found in the case of a tea estate not very far from the Tocklai Experimental Station, where such pests as looper, sandwich caterpillar, nettle grubs, and the like have been so reduced as to be negligible although, in the past, they used to give a good deal of trouble.

From this particular tea estate samples of the chrysalids brought into the factory have been sent from time to time to the entomological laboratory at Tocklai, where they were reared to maturity in order that they might be identified. This has been done since the cold weather 1912-13, by which time the damage done to the tea by caterpillar pests had already been reduced to negligible proportions. In spite of this, however, the numbers of chrysalids destroyed each cold weather runs into thousands and, as the following account shows, the chrysalids collected extend over a considerable variety of forms, many of which, if left alone, might at any time develop into a serious pest of tea, or shade trees, or attain sufficient numbers to render green manuring impracticable.

The following list shows the variety which obtains in the specimens bred out in the Laboratory. There are specimens of

thirty different species of moths, belonging to nine different families* :—

Family.	Species.
Eupterotidæ	near *Sangatissa*.
Sphingidæ	*Acherontia lachesis* F. *Chaerocampa pallicosta* Wlk. *Sataspes ventralis* Butl.
Notodontidæ	*Phalera raya* Moore.
Limacodidæ	*Hyphorma* sp. *Thosea sinensis* Wlk. *Thosea cervina* Moore. *Thosea divergens* Moore. *Altha castaneipars* Moore.
Lasiocampidæ	? near *Suana*.
Hypsidæ	*Hypsa alciphron* Cram.
Noctuidæ	*Agrotis ochracea* Wlk. *Agrotis descripta* Brem. *Agrotis* sp. *Leucania loreyi* (*albistigma* Mo.) Dup. *Leucania decisissima* Wlk. *Arcilasisa plagiata* Wlk. *Spirama retorta* Cram. *Spirama* (*Enmonodia*) *vespertilio* F. ?
Geometridæ	*Biston suppressaria* Guen. *Biston bengaliaria* Guen. *Boarmia selenaria* Hubn. *Boarmia acaciaria* Boisd. *Medasina strixaria* Guen. *Erebomorpha fulgurita* Wlk. *Abraxas sylvata* Scop.
Stenomidæ (*Tineidæ*) ...	*Agriophora rhombota* Meyr.

EUPTEROTIDÆ.

The family *Eupterotidæ* contains the Processionary and Tent caterpillars, so-called from their habit of wandering in procession in the search for food, and of building large silken residences in the branches of trees. The caterpillars are hairy, and the hairs become detached and sting very badly if the caterpillar be handled.

* The nomenclature used, except in the case of *Agriophora*, is that used in Hampson's volumes on Moths in the Fauna of British India series, which, though admittedly out of date, is adhered to for the sake of uniformity.

The social tendency is strongly marked, and when observed they are generally to be found in large numbers, and the damage done is apt to be considerable. Some species defoliate trees, others feed on grasses and low herbage, occasionally doing a little damage to crops. One species is said to be bad on *Cajanus indicus* (Arhar dal) in Ceylon.

The caterpillar of the particular species under reference is not known. The pupa is black, smooth, and squat in form, about three-quarters of an inch long. The anterior half is swollen and bulbous, three-eighths of an inch in diameter at its broadest part, while the posterior half, which is transversely segmented, cylindrical, and bluntly rounded at the end, is five-sixteenths of an inch in diameter. The wings, legs, and antennæ are very little raised from the body, but their outlines can be traced by fine grooves. The soil seems to stick to the pupal case to a considerable extent, giving it a greyish appearance and making the grooves outlining the appendages more distinct.

The moth is of medium size, the wing expanse being two inches or a little less. The body is drab-coloured with a clothing of brown hairs on the thorax, brown feathery antennæ, and large black eyes. The coiled proboscis so conspicuous below the head of most moths is absent. The front wings are of a greyish-white ground colour, profusely speckled with reddish-brown in the manner in which a half-dry paint brush would mark very rough drawing paper. In the centre of the wing an indistinct white mark, somewhat resembling the outline of a wine glass without a stem, is often to be seen. Smudgy, dark-brown, broken lines, lying roughly in the direction of the length of the wing, and one or two dark-brown spots at the outer angle of the wing, give the moth a rather distinctive appearance. The underwing is very pale brown, somewhat darker towards the edge. Of the habits of the adult insect we know little or nothing, but the author captured one which was resting on the trunk of a medeloa tree (*Dalbergia assamica*) at 6 p.m. one evening in August. Resting on the lichen-covered bark, it afforded an excellent example of protective coloration.

Pupae collected in February gave moths in February and March, while pupae collected in March gave moths in May, but that the whole cold weather is spent in the pupal stage is shown by the fact that pupae received in December did not hatch until the following April. These pupae were once found on an estate in the Sonari district in enormous numbers, but did no apparent damage.

The caterpillar of this moth is parasitised by an ichneumon.

SPHINGIDÆ.

This family contains the Death's Head Moths and Hawk Moths. Four different species belonging to this family occur, one Death's Head Moth, two Hawk Moths, and one Bee Hawk Moth.

Acherontia lachesis, referred to here as a Death's Head Moth, is a close relative of the true Death's Head Moth, *Acherontia styx*, which is also fairly common in the tea districts, and bears a great superficial resemblance to that species. It may readily be distinguished, however, by the following characteristics. The upper surface of the abdomen of the true Death's Head is transversely banded in brown and yellow, with a narrow longitudinal grey stripe down the middle. In the case of *lachesis* this stripe is so much broader that only small patches of yellow are visible at the sides. The underside of the abdomen, in the case of the true Death's Head, is yellow, while in the case of *lachesis* it is yellow with transverse brown stripes. The hind wing, also, is different in the two species, that of *lachesis* being readily recognised by having a brown patch at its junction with the body, and two broad transverse brown bands beyond, on a yellow ground, while the true Death's Head has no such brown patch, and only two narrow brown transverse bands.

The caterpillar of the Death's Head Moth is readily recognisable, and most planters are probably familiar with it. It is a large, thick, smooth, green caterpillar which may attain three inches in length, with a kind of tail or horn projecting upwards and backwards from the hind end of the upper surface. On each side of the body are seven or eight prominent oblique yellow stripes, edged above, in the case of *lachesis*, with a blue streak. This insect has

been found to eat the leaves of many leguminous plants, including two such universal green manures as Boga medeloa (*Tephrosia candida*) and Cow pea (*Vigna catiang*), and although it never appears to multiply to any great extent, yet one individual is capable of doing so much damage that one can well imagine a large number making short work of a green manuring programme.

There appear to be two broods of this caterpillar a year. Pupae collected by forking in the cold weather emerge during March and April, lying dormant in the soil for four months or more. Larvae are next found in the field in April and May, pupation takes place in May, and emergence at any time between June and August. The larvae from this second brood enter the chrysalis stage in October or November, and these are the pupae which are found during the cold weather forking.

A parasitic fly has been found to prey upon this caterpillar.

Chaerocampa oldenlandiae, the commoner of the two hawk moths, is a common visitor at light in bungalows in Assam. It is a medium-sized, olive-brown hawk moth, having the typical neat torpedo-shaped body and long, narrow, firm wings of that type of moth. The body is about an inch and a quarter long, the expanse from tip to tip of the wings two and a half to two and three-quarter inches. The forepart of the body is hairy, with the sides edged with white and a central white line. The latter half of the body is smooth, and the middle line changes to two narrow parallel clearly marked white lines. Towards each side of the forepart of the body is a narrow golden stripe, and the sides of the hinder part of the body are streaked with golden yellow. The wings are marked with strongly pronounced diagonal stripes differing in width and in colour from dark brown to pale tawny. In the centre of each forewing is a small distinct black spot. The underside is pale brown, finely speckled with dark brown. The eggs are laid on the leaves of plants, and give rise to a caterpillar of the typical hawk-moth description, but with the head and first two segments more or less retractile into the third, which is considerably swollen. The colour is pale purplish brown, with bands of yellow specks on the back, and crimson spots on the sides with a well-marked black

outline in the younger stages. Later on the crimson spots change colour, the first two becoming blue, the latter purple. This caterpillar is commonly to be found on "kachu" (*Colocasia antiquorum*), the common wild arum of the tea districts, and has been found on mati kalai (*Phaseolus mungo*), so that not only is it a possible pest of green crops, but there is a plentiful supply of another food-plant always available upon which it can flourish and thus be always at hand to do damage.

The pupa is a typical Sphingid pupa, similar in general characteristics to that of the Death's head moth, but smaller, and with a projecting snout beyond the swellings marking the eyes. It may have attached to it, when brought in by the children, the remains of the case of silk and leaves in which it encloses itself in the soil.

Chærocampa pallicosta, the second hawk-moth, was only found once, a pupa received in March 1914 hatching out three days later. The pupa is a little larger than that of the previous moth, and the life history probably very similar. The moth will be readily recognised on emergence. It is a typical hawk-moth, with the front half of the body and the front wings dark russet brown, the hind wings and the hinder part of the body paler red brown. The front edge of the front wings, and the sides of the anterior half of the body, are marked with distinct white lines, and there is a longitudinal white mark down the centre of the front half of the back.

Sataspes ventralis, a bee or humming-bird-hawk-moth, was also found on one occasion, a pupa received in February 1920 giving rise to an adult in April of that year. We are not acquainted with any of the habits of this insect. The adult probably flies at twilight, and the humming note that these insects make in flight may yet lead to its discovery. In appearance the moth is black, with steely-blue-black wings, the upper surface of the head and shoulders lemon yellow, and with flattened tufts of hair on the tail and on the sides towards the tail. The last four segments of the undersurface of the body are also lemon yellow. The whole insect is an inch and a quarter long, with a wing expanse of two and a quarter inches, and is rather squat in appearance.

The damage done by a single specimen of any caterpillar of the hawk-moth type is considerable, and it is well that they seldom attain to any large numbers. It has been found in rearing these insects in captivity, that they are extremely susceptible to variations in environment, and that if specimens are to be reared to maturity at the same time so as to obtain eggs, they must be kept under identical conditions, or they will emerge at such widely different times that eggs cannot be obtained. It may be that this, to a great extent, accounts for the comparatively small number of these insects, and there is no doubt that the systematic collection of the pupae of the second brood when forking in the cold weather will help in controlling such a pest, for any accidental increase in numbers is thus prevented from being carried on to next year.

NOTODONTIDÆ.

Phalera raya is the only member of this family which has been received among the pupae collected in the forking. This is significant, for the lobster caterpillar of tea, *Stauropus alternus*, used to be plentiful, and although it is known to be still there, its numbers are now so small that in a period of seven years the samples of pupae received at Tocklai for examination have not contained a single specimen.

No information is as yet available as to the food plants of *Phalera raya*, but the larva has been described, and is bluish white, with the sides yellow, with a red band. There is a series of hairy warts on the back, and a pair of processes at each end with strong hairs from them. The larva will readily be recognised from its appearance as of a type not far distant from that of the lobster caterpillar.

The pupa is about an inch and a half long, black, and smooth, with the fore-end broader than the hind end, and both ends bluntly rounded. Its general shape is characteristic, but rather difficult to describe. It is the shape acquired by a "Light of Asia" cheroot left out of the drying tin for a month in the rains. Pupae received in February gave moths in March and April, others received in March emerged in April.

The moth is moderately large, with a wing expanse of some three inches in the male and some three and a half inches in the female. The forewings are brown, marked with transverse, very indistinct, waved lines of darker and lighter brown, and with a large tawny patch at the extreme fore-end. The hinder two-thirds of the fore-wings are dusted with silvery white in such a way that when looking directly at the wing it appears brown, but on looking at it at an angle it appears silvery white. The hind wing is brown, dark brown towards the hinder margin, and the body is banded with yellow and dark brown.

LIMACODIDÆ.

This family includes all the moths which form the brown spherical cocoons with such a resemblance to tea seed, and which are commonly known in the tea districts as tea seed cocoons. The caterpillars are slug-like, many of them beautifully coloured and highly ornate, with many spines and hairs and an unenviable reputation for stinging, others resembling nothing so much as a jujube, and well-known to planters as "jelly-bugs." The adults are inconspicuous furry moths, with somewhat shortened and rounded wings and thickset, short bodies, and are generally of a dull-brown colour, though occasional species are brighter.

Of the five species of this family found, three are known as pests of the tea plant, and their caterpillars have made themselves familiar as so-called "nettle grubs."

Thosea sinensis is not uncommon on tea in Assam. The caterpillar is a typical nettle grub, yellow to green in colour, with a paler stripe down the middle of the back, having a red spot at its centre, and two rows of fleshy spines, reddish in colour towards the tips, on each side.

The cocoon is a typical "tea-seed," but rather smaller than that of the commoner "nettle-grubs."

The moth is small, brown, and with a wing expanse of about one and a quarter inches. The forewing is divided by a transverse diagonal brown diffuse line into two areas, that nearer the body being pale brown in colour, that further from the body bein

darker. A small indistinct black spot is to be seen at the centre of the wing, and within the pale area.

The cocoon of this species was received once, in March, and the adult emerged from it in May.

Thosea cervina is the common "nettle-grub" of Assam, which is too well known to require description here. The moth is dark brown, with a wing expanse of one and three-quarter to two inches, with one narrow transverse dark stripe near the tip of each forewing, the dark stripe being edged on the outer side by a lighter stripe.

Some of the cocoons of this species found in the cold weather hatched by the beginning of February, but others emerged as late as the end of April.

Thosea divergens is the so-called "green and brown striped nettle grub" of Assam. The moth of this species is very similar in general appearance to the preceding, but can be distinguished by the fact that the forewing has two transverse stripes, one situated as in *Thosea cervina*, the other, more oblique, between the first one and the body of the moth.

The cocoons of this insect collected in the cold weather gave rise to moths in March and April.

Hyphorma sp.—This is a rarity, only two of the light-brown cocoons having been received, from one of which a parasitic fly emerged. The moth is similar in size and shape to that of the nettle-grub, but is light brown in colour without any particular markings.

Altha castaneipars is another rarity which is probably of little importance, only one cocoon having been received. The life history of this species is not yet known. The moth is less sombre-clad than most of the species of this family, having the forewings yellow suffused with chestnut and the body and hind wings yellow. The adult emerged from the pupa, which was received in March, in May.

LASIOCAMPIDÆ.

This family includes the eggers and lappet moths. Only one species of this family was found to occur, and of this species only one specimen was received in the material collected during forking.

The larva of this moth is a long, grey, hairy caterpillar some three and a half to four inches long, which is not uncommonly found on the trunks of sau trees (where it is only seen with difficulty), and is occasionally to be seen wandering about on roads and even on bungalow verandahs. Its food plant is as yet unknown. Full-grown larvae are to be found in December, and turn into pupae in January, the adult insect emerging in February or March.

The pupa is formed in a cocoon of very coarse silk to which are attached pieces of dead leaf, etc., and the moth is a large, unwieldy, reddish brown insect with a large and fleshy abdomen, and two small white spots on the forewing at a point one-third from the point of attachment and towards the outer edge. When at rest it resembles a dead and crumpled leaf to some extent.

HYPSIDÆ.

Hypsa alciphron is the only member of this family which occurred among the pupae collected.

The caterpillar of this moth has been found to feed on the wild fig or Dumar tree (*Ficus hispida*) round about Tocklai. It and the caterpillar of an allied species *Hypsa ficus* appear to be specific pests of pipal and other trees belonging to the genus *Ficus*, and according to Lefroy are sometimes so abundant as to defoliate large trees "and, standing below an infested tree, one hears their excrements falling in a continuous shower like rain." Watt and Mann record this insect as having once been found on tea, but the occurrence must have been accidental.

The caterpillar is about an inch and three-quarters long, white, with a narrow black band down the middle of the back and two broad, black bands down each side. A series of small black spots will be observed between the black lines, which spots mark small hairy tubercles. The head is large and smooth, reddish-orange in colour, and the upper side of the first segment behind

the head is horny, and orange-coloured with dark-brown markings. The pupa is reddish, and smooth, about an inch long, and is generally enclosed in a "kutcha" cocoon, made of pieces of dead leaf, in the soil.

The moth will be readily recognised. It is of medium size, the wing expanse varying from about two inches in the male to two and a half inches in the female. The body is orange coloured. The front wing is grey-brown, with the veins white, one small white spot in the centre, and a small area at the point of junction with the body orange with black spots. The hind wing is orange, with three black spots on the central area of the wing and an irregular row of black spots near to the rounded hinder margin.

Pupae collected in February emerged as moths in March, and there are probably several broods in the year, for larvae collected on the wild fig on the 10th of July became adult by the 28th.

NOCTUIDÆ.

This family of moths, which includes the surface caterpillars, or cutworms, and the semi-loopers, is a very large and important one including many serious pests, and it is therefore not surprising to find it well represented among the pupae collected on tea gardens, no fewer than nine species of this family having been found. The first three species belong to the genus *Agrotis*, the caterpillars of which generally behave as surface caterpillars, or cutworms, and one species of which, *Agrotis ypsilon*, is considered to be a serious pest in tea nurseries in Ceylon. The life history of these surface caterpillars is somewhat as follows.

The eggs are laid on the stems of low-growing plants or grasses, and may be laid singly or in some numbers, and one moth may deposit eggs for a period of a week or ten days and in different places. The eggs hatch in a period varying from 2 days in the hot weather to 9 days in the colder weather, and give rise to larvae which at first feed on the epidermis of fallen leaves, under which they are generally to be found, but later eat only fresh leaves, which they obtain by cutting through the stem at the ground, and so felling the plant or part of it. Thus the damage done to the

plant may be out of all proportion to the amount of green food actually eaten. The caterpillars of this type may be readily recognised from their habit of coiling themselves into a disc when touched. The caterpillar stage lasts for about a month, when they turn into pupae underground. The pupa is reddish or reddish-brown, smooth, and about three-quarters of an inch long, pointed at the hind end, blunt forward, with the segmented hinder portion capable of a certain amount of movement, with a few needles at the apex. The length of the pupal stage varies from about 10 days in the hot weather to a month or more in the cold weather. All the pupae, of the three species obtained from the material examined, emerged in under five weeks from the date of capture, and moths were obtained in January, February, and March, from pupae collected during those months. One species (*Agrotis descripta*) was found to be parasitised by the same ichneumon which was bred from the *Eupterotid* referred to above, and also by a fly.

The adult insects are small, non-descript, dingy brown moths, with a wing expanse of from an inch and a quarter to an inch and a half.

The next two species belong to the class whose caterpillars are are known as army worms, from the fact that they may be seen in some years going across country in enormous numbers. Most planters have probably seen them on the move at one time or another. At such a time a "bund" road may be covered for hundreds of feet with a writhing mass of caterpillars, so thick that not a trace of the road can be seen. One of the two species recorded, *Leucania albistigma*, is occasionally a serious sporadic pest of rice in India, and is of not uncommon occurrence on graminaceous plants of one kind and another. The caterpillar is about an inch and a half in length when full-grown, smooth, striped longitudinally with olive-brown, reddish-brown, and drab, with the underside olive-green. It hides during the day in cracks in the soil, and feeds at night.

The pupa is smooth red-brown, shining, about three-quarters of an inch long, very similar to that of the Agrotids referred to above.

The moth, in the case of *Leucania albistigma*, has a wing expanse of about an inch and a half, the front wings being of an ochreous or brownish-ochreous colour with obscure, non-descript markings and a small distinct white spot near the middle, the hind wings smoky. That of *Leucania decisissima* is smaller, having a wing expanse of an inch to an inch and a quarter, the front wing straw-coloured, splashed and dotted with brown, the posterior two-thirds of the hind wing brown. *L. decisissima* is not common, having been received only once, in February, the moth emerging from the pupa in the same month.

L. albistigma is commonly received. The pupal period is commonly less than a month, but one case occurred of moths emerging in April from pupae collected in February. It is parasitised by an ichneumon, and by a fly which appears to be identical with that found to parasitise *Agrotis descripta*.

Arcilasisa plagiata is also of common occurrence among the pupae collected in forking. The caterpillar of this moth commonly occurs on indigo (*Indigofera arrecta*) and other indigoferous plants, and may be regarded as a potential pest of any such plant used for green manuring purposes. The eggs are laid on the leaves of the plant, and the larvae are at first gregarious, but later spread. When full grown they are from an inch to an inch and a half long, with a few scattered dots.

The pupa is of a similar character to that of the Noctuids previously referred to, but bigger, being about an inch in length.

The adult moth is likewise larger, having a wing expanse of two inches or more. The front half of the body is drab in colour, the latter half smoky. The front wings are also drab, with a pale area, bounded by an indistinct narrow brown broken line, at the point of junction with the body, a large irregular brown blotch at the centre of the wing near the outer edge, and an indistinct wavy thin yellow line beyond, with a smoky patch beyond it. The hind wings are smoky.

The young caterpillars of the last brood of the season were found on indigo in November. These turned into pupae in

February, and the moths emerged in March. Pupae were received from December to February, and emerged over a period extending from February to April.

Spirama retorta is the next species. This, though apparently common, we know little or nothing about. The pupa is similar in type and general appearance to those of the preceding, but larger and more robust. The moth is of striking appearance, and is probably likely to be mistaken by the uninitiated for a butterfly. With a wing expanse equal only to that of *Arcilasisa*, it is yet a much larger insect, owing to the breadth of its wings. The general colour is brown, paler at the edges, and with narrow, wavy brown and black lines at the extremity of the front wing. In the centre of the front wing is a large black mark rather like a comma, which is exceedingly prominent and quite distinctive. The abdomen of the body is crimson, with triangles of jet black on the centre of the back on each segment except the last, decreasing in size towards the hind end. There are several varieties of this moth. One variety is similarly marked, but lighter in colour. Another variety has the comma much reduced, and with three lobes. In yet another variety the three-lobed comma is reduced to three spots. Moths emerged from all the pupae received, save one, at the middle of March. That one emerged in February.

Spirama (*Enmonodia*) *vespertilio* is a still larger moth than *Spirama retorta*, of similar build, with a wing expanse of three inches. The general colour of the moth is drab with the head and shoulders chestnut brown, the latter half of the body and the fringe of the hind wings the colour of yellow ochre. The general shade of the wings gradually darkens to the hind end. The markings are indistinct, and consist of a diagonal brown line crossing both fore and hind-wings, three small black spots within the diagonal line on the forewing, and an indistinct series of small black spots on the other side of it. This moth is not so common as the previous one.

The pupa is very similar to that of *Spirama retorta*, but a little larger.

One other Noctuid moth was received on one occasion only. It is a very small grey moth, and apparently very rare.

GEOMETRIDÆ.

This family includes the looper caterpillars, so-called because, having no prolegs in the middle of the body, they are constrained to progress by drawing the hind end close up to the fore-end, thus forming themselves into a loop, and then, with the hind end attached, extending the fore-end to take a fresh purchase.

Seven different species occur among the pupae collected on the particular garden under reference at the time of forking.

Biston suppressaria is the common looper caterpillar of tea. This pest used to be very bad on this particular garden, and even now the caterpillars and moths are very often to be seen, but it never occurs in sufficient numbers to do any appreciable damage.

An account of this moth, and of its life history, with descriptions and figures of the various stages, has already been given in Part I of this Journal for 1911, and the emergencies of the insects from the pupae correspond with ithe dates there given for the commencement of the first brood. There can be no doubt of the value of systematic collection of the chrysalids at the time of forking as a means of control of this pest.

The icheumon parasite figured by Antram has, of course, not been found amongst the pupae brought in, since it emerges from the caterpillar before pupation, but a parasitic fly has been bred from the pupae.

Biston bengaliaria is a looper closely allied to the common looper, but may be looked upon as a rarity, since only one specimen has so far been found. The moth is smaller, though of a similar ground colour to *Biston suppressaria*, and can be readily distinguished by the fact that two narrow dark transverse waved lines divide the front wing into three areas of which the centre one is grey, the other two grey splashed with dirty yellow, while a similar line on the hind wing divides the latter into two areas, of which the outer one is smaller, and grey splashed with yellow, while the inner one is grey, with a circular black spot at the centre. The expanse of the wings in this species barely extends to two inches. The pupa received turned into a moth by the middle of February.

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Boarmia selenaria is another looper which is not uncommon.

The caterpillar is a typical looper, about two inches in length when full-grown, and varying in colour from light green to brown. What it feeds on, on the tea garden, is not yet known, probably on the trees, for Stebbing has reported it as an occasional pest of sal (*Shorea robusta*) in the Siwalik ranges.

The moth is grey, but a whiter grey than the looper, and is smaller than that of *Biston bengaliaria*, having a wing-spread of barely two inches. The markings are often very indistinct, but it is generally possible to observe, at about the middle of each wing, an irregular lozenge-shaped pale spot with a dark edge. Pupae of this moth have been received in different years in the month of February, and the time of emergence has varied from February to April.

Boarmia acaciaria is more common than the previous species, to which it is closely related.

The caterpillar feeds on leguminous trees, and occasionally on Sonaru (*Cassia fistula*) in sufficient numbers to do damage.

The moth is smaller than that of *Boarmia selenaria*, having a wing expanse of but an inch and three-quarters. The ground-colour is grey, but a wavy transverse line across each wing a little beyond the middle marks off an outer area which is much suffused with brown, and the hinder part of the abdomen is also brown. Looked at from the underside, the inner part of each wing is dirty white, with one brown spot on it, while the outer area is brown. Adults emerged from pupae of this moth in February and March.

Medasina strixaria is another rarity, only one specimen of which was received.

The moth is similar in size and shape to that of the common looper, but grey-brown in colour. The fore-wing is marked with an oblique wavy pronounced dark-brown line, with a brownish suffusion beyond it, and the hind-wing has a wavy narrow brown line across it just beyond the middle. The specimen received did not emerge as a moth until April.

Erebomorpha fulgurita is a very striking moth, but although it is apparently far from common, nothing appears to be known of its life-history.

It is larger than the looper, having a wing expanse of three inches. It is black brown in colour, and when sitting with the wings closed is triangular in shape, with a bold white triangle on its back, the two sides of which are broad white lines, the base of which is a narrow white line. When the wings are spread open the broad white lines are seen to traverse the front wing diagonally from the tip to the body, and to be continuous with a broad white band across the back, the head and shoulders being dark brown, while the hinder part of the body (the abdomen) is brown on the back, dirty orange at the sides. The hind wing is the same brown-black, somewhat speckled in appearance, with a broad white curved band across it outlined beyond by a strong dark brown line, and irregular splodges of tawny and brown beyond, with an irregular narrow white band. The outer edge of the hind wing is not evenly curved, but is produced at a spot about a quarter of the way back, the projection being white.

This moth emerges from the pupa in March and April.

Abraxas sylvata, the last of the loopers, is not common here, as only one specimen was received.

The moth will be readily recognised by anyone acquainted with home insects as a relative of the common currant moth of England. It has a wing expanse of an inch and three-quarters, and is white, spotted with red-brown and washed-out black. Its food plants and life-history are not yet known.

The moth emerges in March.

TINEIDÆ.

Last, but by no means least of the pupae collected, was that of the well-known Sandwich caterpillar, *Agriophora rhombota.*

The pupae of this moth may be readily distinguished in a heap of mixed pupae by the fact that they wriggle the hind end of the abdomen whenever disturbed. They are about half an inch

long, jet black, and very glossy, the fore-end bluntly rounded, the hind end tapering quickly to a point, segmented, and exceedingly mobile.

The life-history of this pest of tea, which is only too well known in places, has already been dealt with in Watt & Mann's "Pests and Blights of the Tea Plant," and by Antram in Part I of this Journal for 1912.

The small, dirty-white moths emerge from the pupae in February and March.

It is significant that now-a-days no mention is ever made of Sandwich caterpillar as a pest on this garden, though in 1912 it was fairly plentiful on a small area. Since 1914, however, no pupae of this pest have been received, so that it has now become comparatively rare. A further feature of this pupa is that it seems to survive the knocking about in transit, and the removal from the soil, to a less extent than most other pupae. Many of the pupae received, of all kinds, fail to emerge as moths in the laboratory, as the knocking about they receive before arrival is considerable, but in the case of the Sandwich caterpillar very few pupae give moths.

Mention must be made of another type of pupa which is commonly brought in with the moth chrysalides.

This is a long, narrow, cylindrical object, in length from half an inch to an inch according to the species, slightly narrowed towards and bluntly rounded at each end, with an appearance of being composed of a felted mass of fine brown hairs. These are pupae of parasites of various caterpillars, and belong to a family of Ichneumons known as *Ophioninæ*. Theoretically, one would like to have these left in the ground, while other kinds of pupae are collected, but practically it has not been found possible to persuade the children to discriminate. So far four species of these have been collected, and one of these has been found to be parasitised by another ichneumon, so that the principle of "little fleas and lesser fleas" applies in this instance as in others. One would not, therefore, advise any attempt at discrimination, but collect everything, and hope that parasites collected are themselves parasitised.

In illustrating the pupae described above only one, typical of each family, has been illustrated, and those only by outline drawings. It is seldom possible to identify pupae with certainty, but an acquaintance with the general outline of the type of cocoon typical of each family will help one to decide whether the pupae being collected are likely to be those of pests of the jungle, of the paddy in the hoolahs, of green manures and shade trees, or of tea.

It may be argued by some that this article is of little or no practical value, since the idea being to collect everything, a knowledge of what is being collected is of little or no importance. That is as may be, but the object of this note is neither to educate nor instruct, but to interest. One constantly finds it necessary to emphasize the fact that the essential necessity for effective control of our insect pests is that all measures attempted should be done thoroughly. This applies to all measures as yet recommended, from spraying to thullying. When a tea-bush is sprayed it is the few leaves left unsprayed which account for the inefficiency of the operation. When a tea-bush is swabbed with soda-wash, it is the crevices into which it is difficult to get the swab which contain most of the scales and mites, and lack of thoroughness in application may render the whole operation fruitless. Similarly, when a child has collected sufficient chrysalids to bring in so many pice, it is odds on his completing his forking 'nerrick,' without any attempt to collect more, as every planter knows. These control measures, unfortunately, are as yet regarded by the majority of planters as "faltoo jobs," and a nuisance, and as such little interest in them is often evinced save for the fact that doling out the pice may make one late for tennis. It has been the same with all innovations. The present writer, though still a chhota-sahib, can remember a time when the majority of planters had little faith, and less interest, in manuring, with the result that thousands of rupees were wasted annually through manures being applied on any old place at any old time any old how. At the present day most planters discuss manuring even during their hours of recreation with a zest and with an intelligent appreciation of its relative merits and demerits under different circumstances which shows

that they take a lively interest in the subject. The result has been increased returns for the money spent, and time and labour is more judiciously expended.

One looks forward to the time when the same may be said of insect control. Once planters begin to take an interest in the relative value of each measure for different pests, to endeavour to discover what particular species is peculiar to any particular part of the estate, how it varies from year to year, and above all, what particular insects are there which are not doing any damage, and why, we shall attain to a thoroughness in the carrying out of control operations which will lead to a far bigger return for time, labour, and money expended.

This article, therefore, is an attempt to arouse interest in one of the most valuable measures for the control of caterpillar pests, a measure whose value is greater in prevention than cure, and in which it is as important, if not indeed more so, to take a keen interest when the need for it seems to be least.

THE DOOARS SOIL SURVEY,

P. H. Carpenter, F.I.C., F.C.S.

The Dooars and Terai is a subtropical area situated close to the foot of the hills of the Himalayas along the northern boundary of Bengal and is bounded on the West by Nepal and on the East by Assam. The width from North to South is approximately 20 miles. It is a long narrow strip of land with the direction of slope at right angles to its longitudinal axis. Several rivers break out from the hills and cross the area and, owing to the slope of the land are in the rainy season very rapid, carrying large quantities of matter in suspension. The deposits from these rivers have caused in the past deposition of much of the present land in the district and as might be expected there is a correlation between the soil and thé hills towards the North. The soil that has been so deposited is of a sandy or silty nature and comprises the larger part of the soil in this district. There is however in the West centre of the Dooars an entirely different type of soil known as the Red Bank which is a high plateau, much above the level of the sandy soils, and extends from Sylee in the West to Chengmari in the East. This Red Bank soil is as the name implies of a red colour. It is of a clayey nature and has every evidence of being of very great age. There are then two main classes of soil with a distinct line of demarcation between them. They will be considered separately in detail. Before however proceeding to do so a brief summary of the more important geological data is given as this affords information concerning the nature and characteristics of the soils.

To the North of this district are two large masses of gneiss, situated one in the vicinity of Darjeeling, and the other on the Eastern side of the Teesta valley. Between the two is a long narrow area extending from Tibet in the North in a southerly direction to the plains which consists of rock of a secondary formation and known as the Daling clay series. This is of old formation

and probably belongs to the archaean geological formation which is the oldest known. Through the centre of this strip runs the valley of the Teesta. Towards the South, the Daling clay spreads out in a fan shape and occupies the area immediately to the South of the gneiss and forms a band of varying width from East to West comprising the lower sub-Himalayan ranges. This rock reaches to the foot-hills and abuts the Dooars plains at that part where the Red Bank soils are found. Throughout the remaining area the foot-hills running East and West consist of tertiary sand-stone with here and there small areas of dolomite rock having the same easterly and westerly directions. The dolomite rock is found in the foot-hills to the North of the area enclosed by the Toorsa-Dina rivers and again near Jaintia. In addition to the dolomite rock, tufa is found in many scattered places throughout the tertiary area. The soils in the neighbourhood of the tertiary sandstone rocks consist largely of sand but the rivers have their source in the regions beyond and consequently they also carry in suspension the detritus of the gneiss and Daling clay, with the result that the deposits which form the soils are of a very mixed nature, and peculiar types of soil are found.

The rocks from which the soils are formed are of a siliceous nature and contain the common mineral silicates as horn-blende, quartz, felspar, mica, etc.

Soils formed from such material naturally possess similar properties and are all siliceous and acid in character. The degree of the acidity varies with the degree of fineness of the soil constituents. The weathering of such rock particles in situations subjected to high temperature and heavy rainfall, which conditions pertain throughout this district, results eventually in the formation of laterite soils. Throughout the whole of the area under consideration the climatic conditions are similar although rainfall is heavier the nearer an approach is made towards the hills. The average for the district approximates to 200 inches annually. This is however not evenly distributed but is precipitated almost entirely during the south-west monsoon period from June to September. During the remainder of the year but little rain falls. The tem-

perature during November to March is cool and the relative humidity low. In April and May the temperature rises and the days are hot and dry. During the monsoon period both temperature and relative humidity are high, the latter being on an average at about 95 % during the whole of the period, with occasional falls for a few days. During this wet period, conditions are such that vegetation grows luxuriantly. Throughout the district the chief form of agriculture is tea growing under the control of limited liability companies both British and Indian. There is no village cultivation of tea. Towards the Eastern end of the Dooars teagrowing is not carried beyond the Sankos river and a stretch of jungle exists between here and the Assam Tea. Towards the West tea is grown up to the Nepal frontier. The whole of the district is well suited for tea as is evidenced by the appearance of that growing in the district.

Red Bank Soil.

This soil extending from the Lehti river in the West to the Dina in the East is a very old soil that has undergone a considerable amount of weathering as is evidenced by the high percentage of clay and aluminium and iron oxides present.

Clay.

	Top Soil.	Sub-Soil.
Carron	34·49	42·76
Chengmari	37·71	......
Hope	30·22	39·39
Killcott	32·54	33·90
Sylee	32·06	......
Jiti	28·29	36·55
Kurti	37·33	......
Bhogotpur	27·83	27·90
Nagrakata	34·24	38·67
Ghatia Jhalia	30·64	35·80
Nagaisuree	31·94	35·62
Nya Sylee	40·07	......
Meenglas	37·14	35·39
Indong	28·74	27·44
Zurrantee	35·91	26·70
Chalouni	28·47	31·62
Lookean	31·52	......
Sathkyah	36·06	......
Yong Tong	31·17	......

	Alumina.	Iron Oxide*
Nedeem	10·96	6·27
Indong	9·92	6·41
Chalouni	12·68	7·19
Kumai	11·56	6·58
Bhogotpur	12·47	6·99
Hope	11·84	7·28

* Vide Dr. Mann's "Tea Soils of North-East India."

Originally it was probably of a much more sandy nature as is evidenced by the amount of coarse sand still present in some of the soils.

COARSE SAND.

	Top Soil.	Sub-Soil.
Chalouni	24·26	24·88
Killcott	31·41	26·62
Indong	23·80	......
Jiti	22·95	......
Zurrantee	30·45	......
Nagaisuree	23·71	25·73
Meenglas	21·67	......
Yong Tong	21·55	......
Hope	......	23·82

The Red Bank Soil.—Is deep red in colour and corresponds with the old alluvium or *bhangar* of the Indo-Gangetic plains with which it was at one time probably a part, when it extended in an easterly direction into Assam where it now only occurs in isolated areas. It is like the *bhangar* always at a higher level than the new alluvium and in the Dooars the edges are either almost cliff-like or with very steep slopes and it would seem that the portions now remaining are the remanent left from the effects of denudation and erosion. As a sub-soil it is found at great depths in various part of Bengal. The level of the old alluvium in the Dooars is possibly the result of upheaval at the time of formation of the Himalayas and its low level in parts of Bengal is owing to subsidence. The slope of the land in the Dooars gives support to this. The portions of the old alluvium remaining as surface soil are characterised by their

stiffness, and this doubtless accounts for their not having been eroded away entirely.

An examination of the data of the mechanical analyses shows that one of the charcteristics of this soil is the small quantity of fine sand, whether the sample be of the lightest or heaviest type representing this soil. It is almost always present in less quantity then the coarse sand as the following table shows :—

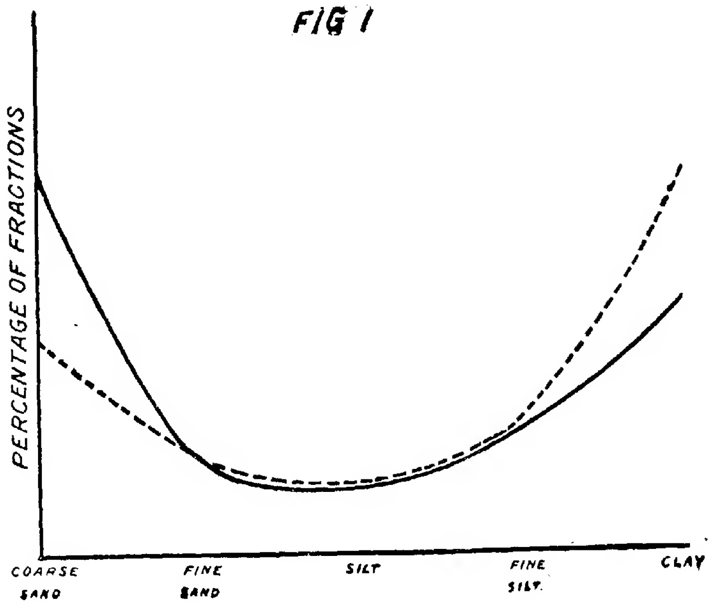
Soil.	Top Soil.		Sub-Soil.	
	Coarse Sand.	Fine Sand.	Coarse Sand.	Fine Sand.
Chalouni	17·64	13·81	21·95	12·69
	......	15·89	18 37	11·10
	......	12·53	13·92	8·75
	......	......	19·55	11·11
	......	......	20 02	7·40
	......	......	......	11·85
Zurrantee	19·93	6·87	21·01	9·37
	18·98	9·41	......	......
Kurti	10·90	11·59	......	......
	10·40	11·52	......	......
	10·53	7·81	......	......
Killcott.	17·51	9·62	20·18	8·54
	......	......	25·04	13·88
	......	......	26·62	13·45
Nagrakatta	6·76	7·47	5·45	6·88
Jiti	23·30	9·67	14·90	7·22
	20·44	10·71	16·04	7·31
	16·93	8·54	18 53	7·65
Hope	14·41	7·84	12 41	6·52
	17·06	8·60	10 32	6·06
	12·82	8·60	11·33	7·39
	14·14	10·85	11·15	7·37
	......	......	16·93	6·74
Nagaisuree	19·99	8·30	23·26	7·38
	27·27	9·16	22·31	9·22
	23·67	7·50	17·73	8·11
	22·88	16·18	25 73	14 06
	23·71	14·68	22·87	16 00
Indong	21·30	13 34	21 30	13·34
	22·14	11·77	......	......
Sylee	15·51	11·34	......	......

Soil.	Top Soil.		Sub-Soil.	
	Coarse Sand.	Fine Sand.	Coarse Sand	Fine Sand.
Nya Sylee	13·93	7·34	......	......
	15·02	8·06	......	......
	10·32	5·67	......	......
	6·22	4·66	......	......
Looksan	19·14	8·30	......	......
Sathkyah	8·57	10·41	......	......
Carron	11·28	8·32	12·79	8.50
	14·72	8·26	11·61	7·26
	15·87	9·23	9·44	7·58
	......	......	13·49	7·14
Chengmari	18·74	4·74	......	......
	13·80	8·10	......	......
	9·35	7·75	......	......
	16·09	5·60	......	......
	15·84	8·08	......	......
Yong Tong	21·55	6·35	......	......
	22·93	9·86	......	......
	20·33	10·46	......	......
Meenglas	16·40	12·71	17·54	12·49
	21·67	13·70	14·97	12·66
	16·73	15·51	13·23	10·77
	......	......	11·00	9·67
	......	......	13·70	18·65

The soils of the Red Bank show two extreme types which may be represented as 1, 5 and 5, 4 types (*vide* "Suggestions for the Manurial Treatment of Tea Soils"—Hope and Carpenter, 5 representing clay and 4 fine silt, the other numbers having an unaltered significance) and these two types gradually merge from one to the other. The variation from one extreme type to the

other can be best shown in the form of a diagrammatic curve representing the amounts of the various factors.

FIG 1



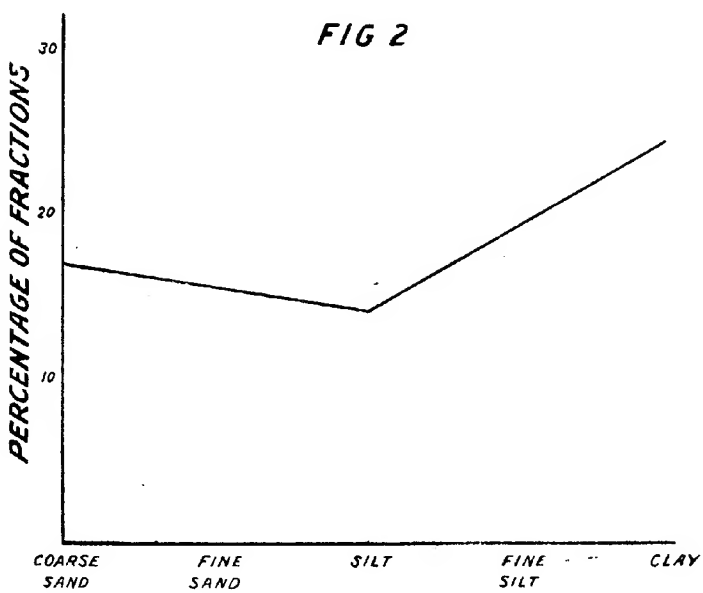
The continuous line shows a soil of the types 1, 5, 4, 2, 3 as found, for instance, at Chalouni, Indong, Killcott, Zurrantee, Jiti as the lightest type of the Red Bank soil whereas the dotted line represents a soil of the types 5, 1, 4, 2, 3 as found at Indong, Nagaisuree, Killcott, Jiti, Zurrantee. A further lowering of the dotted line at the coarse sand end and raising of the clay would result in a soil represented in the extreme case by the types 5, 4, 3, 2, 1 which soils are to be found at Hope, Kurti, Meenglas, Nya Sylee, Nagrakatta. It will be noticed that no great alteration is necessitated in the amount of fine sand, silt, and fine silt present. The change can be represented as a twisting of the curve upon its focus. It will, however, be noted that the degree of curvature

of the curve can be altered and from one of high curvature it can vary to a horizontal straight line in which case all the soil fractions would be present in the same amount. Such soils are not found on the Red Bank, and very few that even approximate to such a type. A very roughly approximate instance occurs in Meenglas.

Coarse sand	16·73
Fine sand	15·51
Silt	14·10
Fine silt	19·81
Clay	25·58

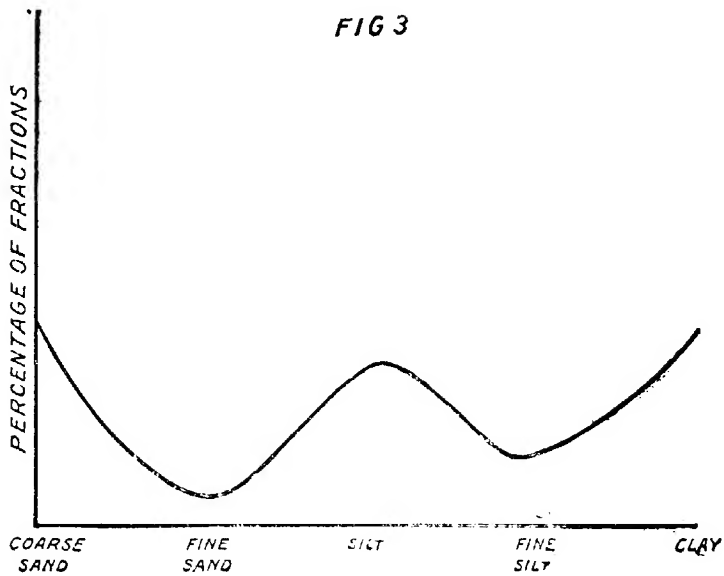
This represented diagrammatically shows that the curve is flattened and tends towards a horizontal straight line when compared with the curves shown above.

FIG 2



Some of the soils are not so simple in constitution and there is a class possessing a high silt content the curve of which is of an entirely different form as shown in Fig. 3.

FIG 3



This is due to the minerals contained in these soils. It would seem that there is considerable resistance to weathering beyond the silt stage but that when the minerals do break down they do so rapidly to the clay stage. Soils of this type are to be found at Chengmari, Chalouni, Nya Sylee, Looksan, Sathkyah, Chulsa and Zurrantee. The above figures represent in diagrammatic form all the classes of Red Bank, old alluvium soils that are found in the district. The soil was the same and it is differences in the weathering that cause differences now in the soil. The average old alluvium soil would possess a mechanical analysis as given below :—

Coarse sand	21·0
Fine sand	10·0
Silt	14·0
Fine silt	18·0
Clay	26·C

and would be represented by soil types 5, 1, 4, 3, 2. The lightest or sandiest type is represented by the soil types 1, 5, 3, 2, 4 and the heaviest by the soil types 5, 4, 3, 2, 1.

The Red Bank soil area of the Dooars can be divided into three parts :—

I.—An area between the Lehti and Neora rivers where no tertiary sandstone formation exists between the Red Bank soil and the Daling clay formation.

II.—An area between the Neora and Jaldacca rivers. In this area there is present tertiary sandstone formation separating the Red Bank soil from the Daling clays of the Himalayan zone.

III.—An area between the Jaldacca and Dina where the Red Bank soil abuts on the Daling clays there being no tertiary sandstone formation.

I. *Lehti-Neora area.*—In this area are found soils varying in type considerably from the heavy types 5, 4, 3, 1, 2 to 5, 1, 3, 2, 4 to 3, 1, 5, 2, 4 and the district generally cannot be considered as being characterised by any one particular type of soil but it is to be noted that the 1, 5, 3, 4, 2 types has not been found to occur.

II. *Neora-Jaidacca area.*—Whilst both heavy and light types of soils occur in this district yet the lighter type of soil represented by 5, 1, 3, 4, 2 to 1, 5, 3, 2, 4 are considerably more in evidence and the heavy type 5, 4, 1, 3, 2 is not so prevalent and but few instances of a 4, 1, 5, 2, 3 types occur.

III. *Jaldacca-Dina area.*—In this area there is a noticeably small number of instances in which soils of the 5, 1, 4, 3, 2 and 5, 1, 3, 4, 2 types occur and the more generally occurring soils are those of the 5, 4, 3, 5, 4, 1 and 5, 3, 4 types.

These districts can then in general terms be shown to possess types of soils that can be connected with the presence or absence of tertiary sandstone formation immediately separating them from the Daling clays. The two districts where the tertiary sandstone

is absent possess generally a heavier soil than the district Neora-Jaldacca where a tertiary sandstone formation occurs.

The following tables show the distribution throughout the Red Bank area of the various types of soil. For this purpose and to save unnecessary complication the two smallest fractions of the soil have been ignored and only the three major fractions have been taken into account. The names of the tea gardens where each soil type occurs is given :—

SOIL TYPE 5, 4, 3.

Hope.	Kurti.	Meenglas.	Nya Sylee
Bhogotpur.	Chatia Jhalia.	Nagrakatta.	

SOIL TYPE 5, 4, 1.

Chengmari.	Chalouni.	Hope.	Jiti.
Killcott.	Sylee.	Zurrantee.	......

SOIL TYPE 5, 1, 4.

Jiti.	Meenglas.	Nagaisuree.	Zurrantee.
Killcott.	Indong.	......	......

SOIL TYPE 5, 1, 3.

Meenglas.	Zurrantee.	Yeng Teng.	Chengmari.

SOIL TYPE 5, 3, 1.

Chengmari.	Chalouni.	Nya Sylee.	Looksan.

SOIL TYPE 5, 3, 4.

Nya Sylee.	Chengmari.	Sathkyah.	Chulsa.

SOIL TYPE 4, 1, 5.

Puttajhora.	Meenglas.	Chalouni.	Hope.

SOIL TYPE 1, 5, 4.

Chalouni.	Killcott.	Indong.	Jiti.

SOIL TYPE 1, 4, 5.

Jiti.	Chalouni.	Zurrantee.	......

Other types of soil occur but are not of general distribution as for instance:—

4, 5, 1 type occurs at	...	Chalouni
5, 1, 2 ,, ,, ,,	...	Nagaisuree
3, 4, 5 ,, ,, ,,	...	Hilla
1, 3, 5 ,, ,, ,,	...	Looksan
3, 1, 5 ,, ,, ,,	...	Soongachi and Indong.

In many of the gardens of this area are to be found soils that are not of the old alluvium type but are of the new alluvium and have been deposited at a comparatively recent date and are the detritus deposited from the present day streams. To this class belong soils such as those of the following types:—

1, 2, 3	...	...	Sathkyah.
1, 3, 2	...	...	Soongachi.
3, 1, 2	...	...	Yong Tong.
3, 4, 1	...	...	Chalouni.
1, 2, 5	...	...	Killcott.
1, 4, 2	...	...	Chengmari, Chalouni.
2, 3, 4	...	...	Nedeem.
1, 2, 4	...	...	Killcott, Sylee.
2, 1, 3	...	...	Sathkyah, Puttajhora.

All the old alluvium soils contain a plentiful store of phosphoric acid and potash and the nitrogen and organic matter is higher than that usually found in tea soils. Noticeable also are the high percentages of lime and magnesia although these are not present in sufficient amount to prevent these soils showing an acid re-action. The high acidity of these soils is characteristic of the type as found in the tea districts and is to be attributed chiefly to the solution of aluminium compounds by strong acids such as nitric, etc. The jungle growing under natural conditions on this soil is marked by an absence of leguminosae which do not thrive on acid soils.

The acidity of these soils varies within wide limits due to several causes but one of the chief of these is the usual form of cultivation in use on tea gardens. The following table shows the

average acidity for the different types of commonly occurring soils :—

Soil type.	Acidity (Veitch Method).
5, 4, 3, 1, 2	3652
5, 3, 1, 4, 2	3321
5, 1, 4, 2, 3	3290
5, 4, 1, 3, 2	3200
5, 1, 3, 4, 2	3137
4, 1, 5, 3, 2	2951
1, 3, 5, 2, 4	2715
1, 5, 4, 3, 2	2261

the acidity tends to decrease as the soils become of a lighter type.

The acidity increases the longer the soil is under cultivation. At the same time the efficiency of the natural drainage of these soils decreases and the longer the soils are under the ordinary conditions of cultivation the greater becomes the necessity for providing means for assisting the natural drainage and hence it is that these soils, which at the time when they were planted with tea possessed a sufficient natural drainage, at the present time are generally in very pressing need of artificial drainage designed with the purpose of aiding and where possible restoring the efficiency of the original natural drainage.

The drainage efficiency of these soils is dependent on the formation of a layer usually between 1-2 feet from the surface which with difficulty only is permeable to water. During the rains a false water table is obtained above this level. In many cases the cutting of drains having outlets at neither end but of sufficient depth to penetrate through the water impervious soil layer to the dryer layers of soil beneath will be sufficient. The true water level during the rains on the high Red Bank plateau soil is at considerable depth.

With increasing necessity for artificial drainage which has not been supplied and an increasing soil acidity these soils show a decreasing fertility which is not due to the lack of potential

plant food in the soil. These soils in good condition represent some of the best types of tea soils.

The attack of tea mosquito *(Helopeltis theivora)* on tea growing on these soils is correlated with the increasing necessity for drainage and the increasing acidity.

The soils of all types are becoming more weathered and the laterisation process is continuing and the soils are consequently becoming heavier and more clayey in nature. Dr. H. H. Mann in his book "The Tea Soils of North-East India" gives the results of analyses from two gardens of old and new soils and the increase in the quantity of alumina present is appreciable.

	CHALOUNI.		BHOGOTPUR.	
	Virgin.	Old.	Virgin.	Old.
Alumina ...	11·58	12·68	11·92	12·47

and this is indicative of the rapidity of the weathering process. The increase in the amount of easily soluble aluminium is in a large measure the cause of the increased soil acidity, *vide* Carpenter and Harler, Part III, I. T. A., *Quarterly Journal 1921*, and is also responsible for the decreasing fertility of these soils.

BLISTER BLIGHT ON TEA.

THE FUNGUS DISEASES OF THE TEA LEAF

BY

A. C. Tunstall, B. Sc.

AND

S. C. Bose.

(Continued from 1921, Part III, page 171.)

Blister blight—*Exobasidium vexans*, Mass.

Blister blight has been known as a blight of tea in Upper Assam for at least 50 years. It was mentioned by Mr. Peal in the Journal of the Agri. Horti. Soc., India, Vol. I proc., June 19th, 1868. He then stated that he had known it ten years before. It was first described scientifically by Massee in 1898 (Kew Bulletin, June 1898) from material sent by Watt in 1895. It was the subject of a pamphlet by Mann (Blister blight of tea, I. T. A. publication No. 3 of 1906). From this pamphlet it appears that the disease was much more severe in Assam than it is at present. In 1907 the disease appeared for the first time in Darjeeling and in 1908 it had spread all over that district causing very severe damage. The outbreak was investigated by McRae, who was sent specially by the Government of India. His investigations were published in the Agricultural Journal of India, Vol. V, part 2, and in pamphlet form in 1910. In spite of these careful investigations the blight continued to cause severe damage, and in 1912 one of the writers was sent to Darjeeling to continue the work. The damage done by the blight is not very serious in Assam and in many gardens it has been eradicated. Occasionally individual gardens suffer severely, but it is not feared very much. In Darjeeling, however, the disease causes severe damage. Darjeeling gardens are unfortunately very close together—no large jungle areas intervene.

It is therefore essential that, in treating a disease like this, gardens co-operate. It was obvious that spasmodic applications of spray fluids were unlikely to eradicate the disease in a district like Darjeeling where the tea gardens are adjoining. It was necessary to learn much more about the disease than the life history of the fungus. The scope of the enquiry was therefore extended and the following points were investigated.

1. The conditions most favourable to the disease :—

Jat of tea
Class of soil
Climate

Aspect
Elevation
Temperature
Rainfall

Cultural conditions

Manuring
Pruning
Plucking

2. The presence of the blight in the jungle on jungle plants or on tea.

3. Experiments :—

Spray fluids
Manurial applications
Modifications in cultural methods

4. Practical methods of dealing with the disease.

Later this work was continued in Assam gardens, and in connection with the presence of the fungus in the jungle special visits were made to the Rhododendron forests of Sikkim and Bhutan. The first part of this article will deal with the description of the fungus and its effects on the plants. With the knowledge gained by the later investigations it is possible to devise a practical scheme for the checking of the disease. The record of these investigations and suggestions for the treatment of the disease will be discussed in the second part.

TEA BUSH AFFECTED BY BLISTER BLIGHT.

"Tea bush affected by Blister Blight. From a photograph by Mr. Claud Bald, Tukvar. The surrounding bushes have been blocked from the background."

(Reprinted from Agricultural Journal of India Vol. V, Part II, by courtesy of Government of India.)

Description of the Disease.

Blister blight usually attacks the young leaves but is also found on succulent green stems of the tea plant. The blight at first appears as round, translucent, pale yellow, sometimes pink, spots on the leaf. As the disease progresses these spots enlarge into white or pinkish convex warts, mostly on the under-surface of the leaf. The opposite surface of the leaf is pale green, yellow or pink, with a concave depression. At a later stage these white convex warts shrink and darken into deep brown, almost black spots. These dried up spots sometimes crack and fall out, leaving round holes in the leaf. When several spots coalesce, or the disease attacks the mid-rib, the leaf becomes curled and distorted.

Examined by a pocket lens, the white surface of the spot is seen to be covered by woolly thread-like outgrowths having a powdery appearance. These are the fructifications of the fungus. A cross section of a spot will show under the microscope, that the cells in the convex part of the leaf have been pushed aside by the fungus, thus causing one side of the leaf to bulge. The cells of the diseased patch of the leaf contain less chlorophyll than the normal, and in some cases the cell contents are changed into reddish coloured substances. The filaments are mostly collected between the cells. Some of them, very much more fragile than the rest, enter the cells themselves. These filaments are divided by many cross walls.

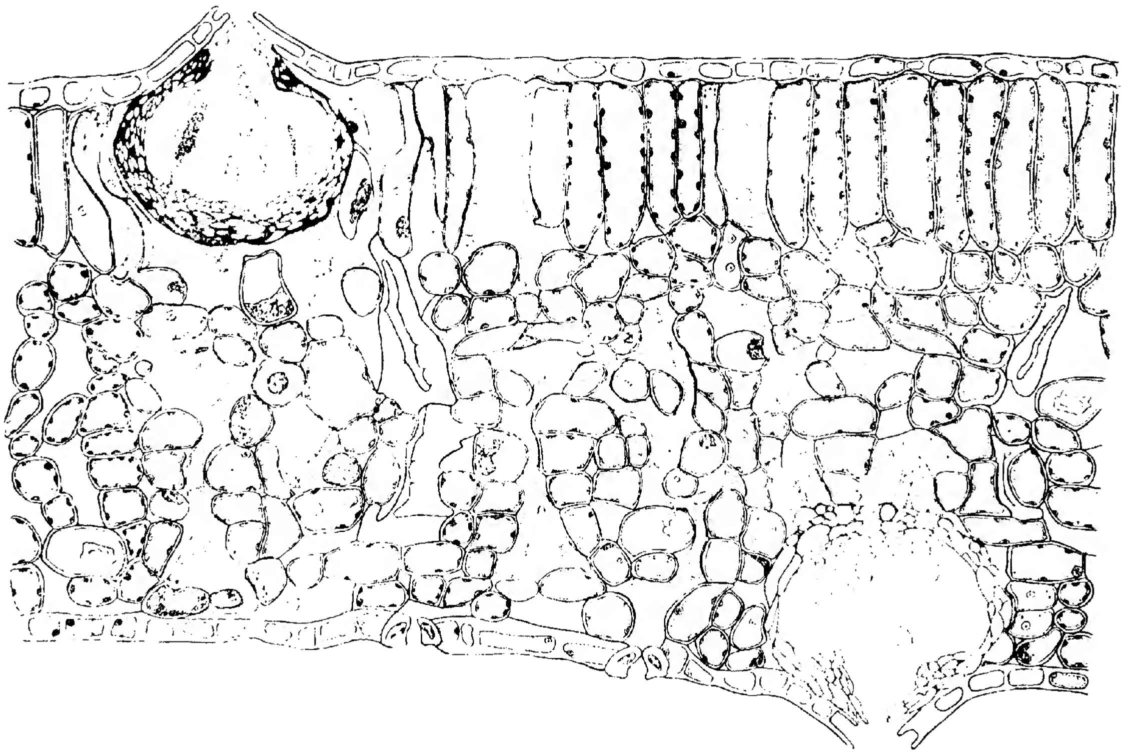
The fungus can be grown in pure culture, but is very susceptible to high temperatures. The isolated spores of both kinds only survive a few hours, and no resting stage of any kind seems to be produced. It is very difficult to get the live blister blight fungus from Darjeeling to Assam. Blister on diseased leaves sent in the ordinary way through the post rarely survives the journey. The infection of the leaf takes place through the stomata, the little mouth-like openings on the under-surface of the leaf. The fungus is purely local, and each blister is the result of a separate infection. The fungus mycelium does not spread beyond the edge of the blister into the other tissues of the leaf or stem. The fungus, under ordinary circumstances, takes 10 or 11 days to develop from

the time of infection to the formation of spores. It then continues to produce spores for 7 or 8 days when the disease dies away. This period is variable according to temperature. At high temperatures 80°—90° F, the fungus does not cause any appreciable damage. At low temperatures 40°—50° F, the development is very slow. The optimum for the fungus seems to be between 65°—75° F. The fructifications of the fungus arise from bundles of mycelium which push their way through the skin, forming a continuous layer of vertical filaments or hyphae over the surface of the leaf. The end of each hypha or filament swells like a club. Some of these remain so, without undergoing any further change. In others the swollen end is separated from the rest by a wall, giving rise to a spore, known as conidiospore. This is the commoner form of fructification. In the early part of the season, and occasionally at other times, other filaments grow out 2 to 5 little horns called sterigmata. At the end of each of these horns a spore is formed. The filament with the horns and spores is called a basidium, and this kind of spore is called a basidiospore. This method of fructification is characteristic of the group of fungi to which blister blight belongs. Other members of this group have special protecting devices, *e. g.*, the pores of the bracket fungi, or the gills of the mushrooms, etc. In the case of blister blight the basidia are formed outside, on the surface, hence the name *Exobasidium*. The reason for the other part of the name—*vexans*—is obvious to planters. There are species of *Exobasidium* present all over the Rhododendron forests to the North-East of Darjeeling.

The Conidiospores are usually single cells but occasionally are uniseptate. They measure 11 to 21 μ by 4·5 to 6·5 μ.

The basidiospores measure 7 to 13·5 μ by 2·3 to 4·5 μ, and are sausage-shaped, hyaline bodies. The size and shape vary considerably.

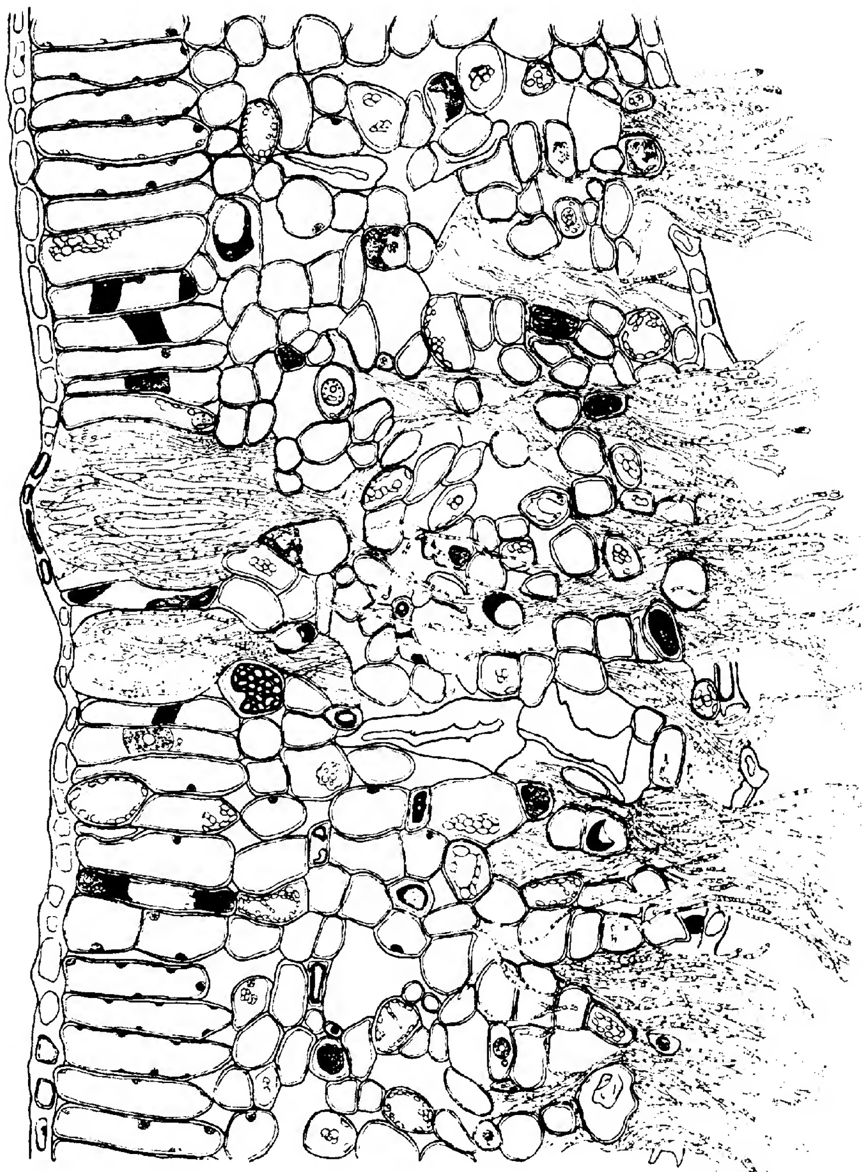
Blister blight not only attacks the leaves and shoots but also the young seeds. These are aborted and sometimes swell up to the size of a walnut. The seeds are not commonly attacked because they are not usually present at the time of the year when



A diagram showing the effect of Copper blight on a cross section of leaf as illustrated in the first part of this series of articles (Vide Quarterly Journal Part III of 1919).

Note the two forms of fructifications of the fungus.

(This diagram should have been published to face page 168 in Part III. of this Journal),



A diagram showing the effect of Blister blight on a cross section of leaf similar to that illustrated in the first part of this series of articles. (Vide Quarterly Journal Part III. of 1919).

Note the two forms of spores of the fungus.

the disease is most prevalent. The seeds attacked by the disease never mature.

When the disease attacks the succullent stems of heavy pruned tea the results are disastrous. In some cases the bushes are killed right out. The spread of the disease is extraordinarily rapid under favourable conditions. Sometimes in Darjeeling whole sections appear white with the disease. The whiteness soon changes to black as the shoots crumple up and decay.

SOME PHYSICAL CONSTANTS OF SOIL,

C. R. Harler, B. Sc., A.I.C.

The Mechanical Analysis of Soils.

The methods of mechanical analysis of soils are based either on the hydraulic principle or on the sedimentation process. The former method was developed by Schöne, Hilgard and Nobel and is only suited to laboratories which work chiefly on soil analysis. The sedimentation process has been developed by Hall (6) and has been modified and hastened by centrifuges (12). The centrifuge is common in the United States where the method has been standardised by the Bureau of Soils.

No scientific grouping of soil particles has yet been devised. In most schemes the ratios between the grades vary widely. Below are shown three different systems, one, that of Hopkins, which observes a constant factor 3·16—the square root of 10—and those of the U. S. Bureau of Soils and of Hall.

Group No.	Hopkins.		U. S. Bureau.		Hall.	
	Grade.	Factor.	Grade.	Factor.	Grade.	Factor.
	mm.		mm.		mm.	
1	1·0000	...	2·000	...	3 000	...
2	0·3160	3 16	1·000	2	1·000	3
3	0 0100	3·16	0 500	2	0·200	5
4	0·0031	3·16	0·250	2	0 040	5
5	0 0001	3·16	0·100	2·5	0·010	4
6	...	...	0·050	2	0·002	5
7	...	..	0 005	10	...	...

During the past ten years the Scientific Department of the Indian Tea Association has been carrying out a soil survey of the tea districts of North-east India. Situated as the laboratories are, a simple method of analysis is essential and on this account the method suggested by Hall was adopted.

The factor or relationship between the various grades in any grouping of soil particles must always be a problem, for, in order that the analysis shall be carried out within a limited time, certain fractions, the larger and probably less important ones admittedly, must have such a wide range that two soils giving similar analyses may vary widely. In the Brahmaputra Valley the deposition of the soil has been such that these differences are common and although it is possible to place fairly accurately a soil by means of its mechanical analysis, yet, such an analysis must be taken only as a first and general classification.

The Grading of a Soil.

A mechanical analysis does not give an idea of the interrelations between the different particles or of the *ensemble* of a soil. Such a value can only be obtained by studying the soil as a whole which it is impossible to do for the physical and chemical properties of a soil are so closely related that they are inter-dependent. Keen (9) has shown that the evaporation of water from a soil is greatly influenced by the colloidal content. The colloidal content is in turn influenced by the chemical nature of the soil particles. The physical properties of a soil are dependent on the inter-relations between the particles, and each soil is a definite entity to which the idea of mechanical analysis is foreign.

Next to the percentage of small particles in a soil, the grading of the particles is the most important factor in determining the tractability or otherwise of the soil. If the percentage of the different fractions is such that the whole soil is able to fit into a compact mass then the soil may be said to be evenly graded and it will be difficult to work. Soils which are of recent deposition such as those near the banks of the Brahmaputra river are hardly likely to be evenly graded but after weathering these soils become very compact and difficult although the extra stiffness is greater than that which would be expected from the difference shown by the mechanical analysis.

Unless a particle fits in with the rest of the soil particles it practically comes outside the physics of the soil. If the particles

are small enough, *i. e.* of the clay order, and become comparable in size with the thickness of the moisture film in the soil then they naturally fit in with the rest of the soil. The addition of coarse sand to a heavy clay merely dilutes the soil and does not render it any more tractable. To illustrate this point, a heavy clay, No. 48* (Borhat) was mixed with quantities, varying from 10 to 80%, of coarse sand. The original soil is an unkind, yellow clay with an optimum moisture value of 29% and a puddle value of 36%. These values, as is denoted later, suggest an evenly graded clay. The addition of sand lowered the moisture figures but the soil still remained unkind. Over 70% addition of sand gave the mixture the characteristics of a sand and no moisture values could be obtained.

As more sand is added to the soil moisture values decrease, by virtue of the removal of the soil, and increase, to a much less extent, by virtue of the sand added. Taking the optimum value of sand as 2·48% as is given by Briggs and Shantz (3) then the optimum value of the diluted soil can be calculated.

The table below shows the moisture values obtained and the third column gives the calculated optimum.

——	Moisture Values.		Calculated Optimum.
	Optimum.	Puddle.	
No. 48, Borhat Soil	27	34	......
" " +10% Sand ...	25	32	24 6
" " +20% " ...	23·5	29·5	22·1
" " +30% " ...	23	25·5	19·7
" " +40% " ...	21·5	23	17·2
" " +50% " ...	18	23	15·0
" " +60% " ...	17	21	12·3
" " +70% " ...	15	18·5	9·85
" " +80% " ...	not obtainable		

It will be observed that as the sand percentage increases the calculated optimum diverges more and more from the value obtained. This suggests that we are dealing less and less with a mixture whose properties can be calculated from the sum of those

* These figures refer to soil number in Tables at end.

of its components. With the higher sand percentage we are dealing with the dilution of a sand with a clay. This has been successfully carried out in parts of England where waste sandy land has been reclaimed (8).

Soil No. 36 (Kurti, Dooars) is a clay with a recent deposit of coarse sand. The sand appears separate from the rest of the soil which for purposes of working is still a stiff clay.

Another, much lighter soil, was also treated in the same manner as Borhat soil. The sample used was No. 37 (Bhogotpore) giving optimum and puddle values 19% and 34% respectively showing it to be a clay silt. The table below shows the effect of sand on the moisture values.

——	Moisture Values.		Calculated Optimum.
	Optimum.	Puddle.	
No. 37, Bhogotpore soil ...	19·5	33·5	......
" " +10% sand	19·0	32·5	17·8
" " +20% "	17·5	30·5	16·1
" " +30% "	17·0	27·0	14·4
" " +40% "	16·0	26·0	12·7

As with the heavier soil mentioned above, the effect of the sand appears to be least when the fraction is small. As the extraneous fraction increases the calculated optimum falls away from the actual value showing that a fresh soil with another entity is being formed. With the higher percentages of sand we are dealing less and less with a mixture and more and more with a soil. A sand can be stiffened by small additions of clay but a clay cannot be rendered appreciably more tractable by a small addition of sand.

Tilth and Condition of Soil.

Tilth is impossible to define from the scientific point of view. Practical men say that at a certain period the soil is in good tilth and a few hours later, after a heavy fall of rain, that it is in bad tilth. To the practical man tilth involves many factors and a soil in good tilth is said to have a "crumb" in it, to have a "live"

look or to be in "good heart." Scientifically it is impossible to deal with such an elusive, indefinite quantity.

Two factors, and possibly the most important in tilth, are the state of aggregation of the particles and the grading of the soil particles and aggregates.

In the tea districts of North-East India is being experienced at present the result of the destruction of tilth in the soil. In countries where the plough is used, tilth destruction is fairly rapid if the soil is worked in wet weather, but the shearing force of the hoe, as it is employed in Assam, is not comparable with that of the mould-board of a plough. The consequence is that the result of incorrect cultivation is only appearing after an interval of 15 or more years.

Since the term "tilth" has no specific meaning, it is advisable to use the term *Condition* to express the state of aggregation of the soil particles. There must be an optimum state of aggregation of the particles in a soil. As the state of aggregation varies so no doubt the other optimum physical constants of the soil vary, for these constants depend on soil condition as it actually is not on what it is capable of being.

The Moisture Values of a Soil.

According to Bouyoucos (1) the moisture in a soil consists of free and unfree water. The unfree water is that of hydration and of chemical combination and also hygroscopic moisture which is less unfree than the first two types. Keen (10) supposes that there is no distinct line of demarkation between these different types of soil moisture and by mathematical methods comes to the conclusion that one type of moisture merges by imperceptible stages into another. Whether the types are distinct or related is immaterial in the present argument. The important point is that a certain quantity of the moisture is less free than the rest. Bouyoucos (2) has shown that this quantity is independent of the total moisture content of the soil.

Unfree water may also be defined as that which is not available to the plant.

The moisture values considered in the present paper are the optimum given by water and ammonia and the puddle content given by water and ammonia. Briggs and Shantz (3) have attempted to calculate some of the moisture values—the moisture co-efficient, the moisture equivalent (optimum), the moisture holding capacity and the wilting co-efficient—from the mechanical analyses of the soils.

In a later work, Smith (11) has shown that the values obtained by calculation are unsatisfactory and that most soils require a separate factor. This can be well understood, for the grading is not shown by an ordinary mechanical analysis, nor is the true clay content or the colloidal content of the soil expressed, unless the loss on ignition of the clay fraction be taken as a measure of this quantity.

The most important water content of a soil is that at the optimum. There are many methods by which the optimum may be determined, among which may be mentioned the penetration method of Cameron and Gallagher (4) in which the weight required to press a sharp instrument into the soil is observed. The force required is smallest at the optimum. Another simple method is that of Davis (5). A tube containing soil is stood in water and after equilibrium has been attained, the water in the top few moist inches of the soil is estimated. This method is based on the fact that the optimum water content of a soil is the maximum amount of water capable of being held by capillarity.

Another method of estimating the optimum water content will now be described. Into a 3″ evaporating basin, 10 grams air-dried soil is weighed. Water from a burette is added drop by drop and the soil is worked with a bone spatula and the water thus distributed. As the water is added a cohesiveness suddenly becomes apparent and the soil instantly takes on a new appearance. The addition of a further drop or two leads to stickiness. The point at which cohesion is observed is the optimum condition and can be easily recognised even by an Indian cultivator with no scientific training and such a man can easily duplicate moisture experiments. The moisture in the soil is then estimated and calculated on 100 grams dry soil.

The puddle condition is estimated in a similar manner. Here again the soil assumes different properties in a very marked manner and the point when all the free space in the soil appears to be occupied by water is easily recognisable. The puddle value is not the same as the water holding capacity which is a greater quantity owing to the fact that a looser packing is observed. In estimating the puddle the soil is well pressed down with the spatula.

The function of the soil moisture at the optimum condition will now be considered. Part of this moisture, that bound chemically and that engaged in solid solution, is totally unfree. The hygroscopic moisture is less unfree than the former, but it is unfree to the plant at the wilting point according to Briggs and Shantz (3). The rest of the water is free and, together with the hygroscopic moisture, makes up the film in which the particles float. The thickness of this film will depend on the shape and size of the particles and aggregates, but the amount of water forming the film is roughly a measure of the surface area of the soil particles. If we denote the free or surface water by (a) and the unfree water by (x) then we may say :—

$$\text{optimum water} = a + x$$

At the puddle state we may suppose that in addition to satisfying the hygroscopic and combined water needs of the soil, which will be the same as before as Bouyoucos (2) has shown, we are covering the particles with a film of water and we are also filling up the interspace (s) between the particles. With one working with water it is difficult to break down the aggregates in a soil so that the loss in condition is not restored on drying, and therefore it is probable that the quantity (a) is about the same with the optimum as with the puddle moisture content. We may say then :—

$$\text{puddle water} = a + s + x$$

Then (puddle–optimum) $= s$, the free space in the soil.

If the soil is puddled with ammonia, the aggregates are broken down and the puddle is arrived at much more easily than if

water be employed. The table shows the effect of puddling with different strengths of ammonia.

Strength ammonia.	Puddle value Calc. 100 gms. dry soil.
Nil	30 %
0·125 N	23 %
0·420 N	19·7 %
0·625 N	18·6 %
0·937 N	18·6 %
1·250 N	18·6 %
about 16 N	18·1 %

Accordingly ammonia of strength about normal may be employed.

The moisture used in the ammonia puddle is employed first of all in satisfying the "unfree" moisture requirement of the soil. It is assumed that this is not materially altered by the addition of ammonia. Moisture is also used in covering the soil particles, for all the aggregates are broken down and a new surface (a') is introduced. In addition a new free space (s'), much smaller than the old free space (s), is introduced. We may then say:—

$$\text{puddle ammonia} = a' + s' + x'$$

where (x') represents the unfree moisture. This value (x') may or may not be equal to the value (x) introduced in connection with moisture values with water. However, this point is immaterial at present.

Unless the optimum value for the completely degraded soil be obtained the value (s') cannot be calculated. With great difficulty can an optimum value be obtained with ammonia. Unless the soil sample is carefully worked, local puddling occurs and in this case it is almost impossible to again obtain equal distribution of moisture.

$$\text{The optimum ammonia} = a' + x'$$

(Puddle ammonia-optimum ammonia) $= s'$ *i. e.* the free space in the soil when complete deflocculation is realised.

It might be suggested that a better method of obtaining the value $(a'+x')$ and one involving less assumptions, would be to deflocculate the soil, and after drying, then to estimate the optimum with water. However, several attempts showed that however complete deflocculation may be, drying results in aggregation.

Several assumptions have been made. It is assumed that the thickness of the film is the same with water as with ammonia and that the chemical action of the ammonia is negligible so far as the moisture values are concerned. The action of ammonia on the colloidal content is not considered and this factor may be of great importance (cf. Keen (9)) in spacing as it is in other physical properties of the soil.

The ratio $\left(\frac{S}{S'}\right)$ gives a measure of the state of aggregation of the particles and may be termed the *Condition Factor* of the soil.

In estimating the optimum with ammonia we are increasing the soil area exposed. This results in a higher optimum than in the case with water. With the ammonia puddle the exposed soil area is increased but the interspace is decreased and the total result is invariably a smaller puddle with ammonia than with water.

The moisture values will be best appreciated from the tables below which give analyses by Hall's sedimentation process. The loss on ignition of the whole soil and of the clay fraction is given, the latter value being an indication of the colloidal matter or true clay present.

In the Brahmaputra Valley there are practically no loams in the usually accepted meaning of the term, for the great majority of the soils are poor in organic matter. A convenient method of nomenclature is that suggested by Hope and Carpenter (7). The five soil fractions, coarse and fine sand, silt and fine silt and clay are numbered 1 to 5. A soil may be quickly described by putting these numbers in order according to the percentage of each fraction in the soil. Thus a soil designated 34521 is one in which the greatest fraction is silt, the next fine silt and so on. Generally

the first two figures give sufficient indication of the nature of the soil.

The Sands.—Below in Table I are shown a number of sands, all of the 1—2 type except No. 4 (Bandasulia No. 17, 18″—27″) which is of the type 2—1. The characteristic of the larger sand particles is their lack of cohesion, for all these soils give no easily recognisable optimum and puddle values. In the Brahmaputra Valley such soils are very common, and with green cropping and lime, which acts as a cement, they almost invariably make good tea lands.

The Sandy Silts.—These soils are shown in Table II. Like sands they are usually of the 1—2 type although the quantities of coarse and fine sand are much more alike.

There are two types of sandy silts in the Brahmaputra Valley. First there are those which have been deposited as such, like No. 11 (Budlabhetta), and No. 14 (Chatlapore Trench). These soils are often of such uneven grading that the moisture values may be much lower than would be anticipated from the mechanical analyses.

The second type are those soils which have suffered weathering and hence tend towards even grading. No. 18 (Pabhojan 24″) is a soil of this type.

Soil No. 16 (Ellenbarie) is interesting, in that its analysis suggests a sand. The soil has, however, been systematically green cropped and acts like a sandy silt.

The optimum value for a sandy silt has a minimum limit of about 9%. Much below this the optimum cannot be recognised. The puddle value is about 18%.

The Clay Silts.—In Table IV are given some soils classed as clay silts. There is no distinct line separating these soils from sandy silts or clays, but the moisture values are usually about 18% optimum and 30% or over for the puddle.

It will be noticed that Nos. 34 and 35 (Behora samples) both act as sandy silts rather than clay silts, which suggests that the clay

fraction is chiefly very fine silt and not true colloidal clay. This is borne out by the small loss on ignition of the clay fraction.

The Silts.—In Table III the silts are shown. The typical soils of Assam are sandy silts or silty sands of the type 4—2 or 2—4.

The silts are characterised by the great difference between the optimum and puddle moisture. The moisture values are only obtained with difficulty and in this respect the silts approach the sands. This class of soil is invariably poor in colloidal matter as is shown by the small loss on ignition of the clay fraction which is in the neighbourhood of 0·1%.

Silts are such, in most cases, because of inherent properties of the particles which resist further degradation after the fine silt stage is reached or by reason of the manner of deposition.

In some cases, sandy soils have weathered to the silt stage and no further. Such soils often consist chiefly of fine sand and silt with very little true clay. Ultimately these soils become silts and little else. Such soils are common in the Dima Toorsa District and Nos. 31, 21, 22 (Toorsa Sec. 5, Woodbine No. 2, and Budlabhetta No. 6) are examples of this type.

For these reasons it will be understood that silts are a class of soils somewhat apart from the others.

The optimum value is usually between 10 and 16% and the puddle value is much higher and usually in the neighbourhood of 30%. This divergence indicates a large free space. No. 32 (Dimakusi) in Table IV is obviously a silt although it appears with the clay silts. The smaller particles in this case are silt and not clay particles.

The condition of silts is best improved by green cropping and liming and in this manner they resemble sands.

The Clays.—The clays are shown in Table V below. Each soil is considered separately.

No. 41 (Suffry) is a grey clay from under a coal seam in the Sibsagar District. It is practically a potter's clay and is so unkind that

it is almost impossible to get an optimum figure because of local puddling. The condition factor is seen to be very small. Such soils are particularly troublesome to work because owing to the shortage of true clay, lime has little effect. The only useful method of treating such soils is to lay them down in grass.

No. 42 (Binnaguri No. 7 of 5) is a soil in good tilth and situated on a sandy ridge, that is to say a ridge which is sandy compared with the soil below the ridge. It is an open soil although it is a heavy clay.

No. 43 (Binnaguri No. 4 of 10) is a good soil giving the moisture figures of a silt and the silty nature is also borne out by the very low loss on ignition of the clay fraction.

No. 44 (Nagrakata) is a dark red soil from the Dooars, well weathered, and very rich in organic matter. It is an example of a soil in poor condition.

No. 45 (Namrup No. 17), is a top soil and may be compared with No. 46 (Namrup No. 1, bottom) the subsoil. The bottom soil is quite distinct. From the high solubility in acid together with the high moisture values a compact soil is suggested. This sample seems to have been taken from the pan area.

No. 47 (Chalounie, subsoil, Engo, No. 8) is typical clay on the light side in good condition. The top soil of this area is in poor condition.

No. 48 (Borhat, subsoil) is a yellow clay, well weathered and probably containing a high percentage of highly hydrated minerals. Its moisture values show it to be a very heavy soil in fair condition.

No. 41 (Hantapara) is a grey, heavy silt as is evidenced by the wide divergence between the two first moisture values. The clay fraction is practically all finely divided silt.

No. 42 (Hilla) is a subsoil of a silty nature.

It is obvious that one type of soil gradually merges into another. The table below gives moisture values for typical soils

calculated on dry soil. These values like all the others are of a preliminary nature :—

Table showing approximate values for Typical Soils.

Soil.	Moisture Values.	
	Optimum.	Puddle.
Sand	......	......
Sandy silt	9 %	19 %
Clay silt	18 %	30 % or over.
Silt	14 %	30 %
Clay	20 %	35 % or over.

The Significance of the Condition Factor.

First consider the case of a soil in which all the particles are separate, *i. e.*, there is no aggregation. Then the ammonia values for the optimum and puddle would be almost the same as the water values, and the free space would be the same in both cases.

In such a soil we get--

Condition Factor—$\left(\frac{S}{S'}\right) = 1.$

And such a soil may be said to be in no condition.

As aggregation increases the factor increases. It is necessary here to define "aggregation," for if the process of aggregation is pushed to ultimate ends the soil finally becomes one great aggregate with no condition at all. Aggregation from the agricultural point of view means a tendency towards "crumb" structure. Beyond this stage, aggregation becomes puddling.

It is necessary at this stage to consider the force which holds the soils aggregates together. Part of the force is due to the capillary action of the soil moisture and part is no doubt due to the cementing action of the soil colloids. As the soil becomes wetter, the cementing *gel* becomes more and more mobile until at the full puddle each separate particle is floating in water or in a very dilute soil solution. At the optimum these forces are well balanced and the desired "crumb" structure results.

So far it has not been possible to get a soil into a condition such that its condition factor is unity.

If a soil is puddled with water and then dried, it regains most of its former condition. Drying evidently does much to put a soil into good condition. It seems probable that condition is most easily destroyed by cultivation of wet soil followed by heavy rainfall. Then the broken down aggregates are washed apart before the chance of aggregation, which comes with drying, occurs.

Several soils were puddled with ammonia and dried, but on drying these soils, like those puddled with water, also took on some condition. This may of course be due to the fact that on drying the soil the removal of the electric charge which brings about deflocculation allows the particles to flocculate again. The taking on of condition may also be due to a process of cementation. The figures below are instructive.

The Table shows the moisture values of original soils and of the same soils after they have been puddled with ammonia and dried :—

Soil.	Optimum.		Puddle.		Condition Factor. $\left(\frac{s}{s'}\right)$
	Ammonia.	Water.	Ammonia.	Water.	
Original Chalounie ...	20 %	18·8 %	26·6 %	33·6 %	2·3
Ammonia puddled Chalounie	18·6 %	15·5 %	27·6 %	28 %	1·4
Original Numaligarh ...	10 %	9 %	14 %	17·5 %	2·1
Ammo. puddled Numaligarh	9 %	8 %	14 %	15 %	1·4
Original Leesh River ...	21 %	19 %	28·5 %	31 %	1·6
Ammo. puddled Leesh River	19·9 %	17·9 %	28 %	28 %	1·25

In each case the condition factor is considerably lowered. It is also interesting to note that the puddle value with ammonia is unaltered by previous puddling. This is what might be expected.

An interesting case of the variation in the condition factor is given by two soils at Tocklai, one grassed down and the other under

good cultivation for about 7 years. The component values are difficult to explain.

Soil.	Optimum.		Puddle.		Condition Factor. $\left(\frac{s}{s'}\right)$
	Ammonia.	Water.	Ammonia.	Water.	
Tocklai ... grassed ...	11·8	10·8	17·9	20·96	1·6
„ ... cultivated ...	12·0	9·0	16·5	18·5	2·1

The cultivated soil has been well limed and liberally green manured, and although the mechanical analyses are similar the condition of the two soils is quite different.

It is not possible at present to give any definite value to denote good and bad tilth but a study of the tables below shows that the value seems to rise from 1·5 to 2·5 as the soil becomes heavier. Silts give, as might be expected, low condition factors since they are like sands incapable of aggregation to the same extent as other soils.

The values given are of a preliminary nature.

Table I.

Sands.

Showing various Soil Fractions obtained by Sedimentation Process.

The Moisture Values are not obtainable by the method described above.

No.	Soil.	Sol. in acid.	Coarse sand.	Fine sand.	Silt.	Fine silt.	Clay.	Loss on ignition.
1	Dhoedaam	1·52	50·62	22·62	6·50	11·60	3·20	4·20
2	Rajabhat	0·57	60·61	33·78	2·61	1·81	Nil.	0·95
3	Mijikajan	0·40	55.62	36·36	2·99	2·23	0·23	1·74
4	Bandasulia No. 17, 18″-27″	0 15	41·47	48·49	5·03	2·45	1·18	1·13
5	Bandasulia No. 17, 4′-4′ 6″...	0·37	68·96	21·99	3·77	3·02	0·65	1·36
6	Dalsingpara	1·41	67·79	19·50	3·47	4·93	1·17	1·66
7	Margaret's Hope ...	0·08	71·53	16·53	4·23	3 78	0·32	3·50
8	Killcot	0·15	64·81	21·14	4·38	2·07	4·48	2·82
9	Lallamookh	0·27	72 55	15·18	2·97	5·92	0·43	1·32
10	Borbhetta	0·16	77·76	19·35	0·98	0·58	0·58	0·88

TABLE II.

SANDY SILTS.

Showing various Soil Fractions obtained by Sedimentation Process together with Moisture Values and Condition Factor.

No.	Soil.	Sol. in acid.	Coarse sand.	Fine sand.	Silt.	Fine silt.	Clay.	Loss on ignition.	Loss on ignition clay.	Moisture Values. Optimum. Water.	Moisture Values. Optimum. Ammonia.	Moisture Values. Puddle. Water.	Moisture Values. Puddle. Ammonia.	Condition Factor.
11	Budlabhetta	1·48	41·00	22·92	13·42	11·36	6·84	2·81	0·81	8·2	9·2	17·3	14·8	1·63
12	Koliani	0·64	39 01	26 50	10·54	10·31	10·22	2·05	0·13	6·4	7·4	14·5	10·5	2·58
13	Chatlapore Top	2·78	33·23	30·36	8·35	5·84	17·61	4·44	0·42	8·6	13·5	16·3	13·7	1·83
14	Chatlapore Trench	3·58	36·11	27·51	7·89	9·01	14·79	4·21	0·39	8·4	9·9	15·6	13 0	2·32
15	Shamsanagar	0·62	29·79	24·28	15·40	8 85	15·97	4·18	0·53	8·6	9·6	16·9	13·2	2·30
16	Ellenbarie	3 83	60·88	18 05	6·47	7·36	1·60	4 60	0·03	9·9	10·9	20 2	18·6	1·34
17	Pabhojan 24″	0·53	37·14	28 67	8·96	10·79	10 89	3·07	0·15	8·5	9·5	17·6	14 6	1·59
18	Pabhojan No. 8, 9″	0 54	28·67	35·39	12·15	10.82	7·66	4·84	0·09	9·1	10·1	20·4	17·3	1·57
19	Binnaguri	0·53	49·26	19·79	5·43	8 57	10·81	3·11	0·23	9·3	10·3	15·5	12·9	2·38
20	Kanjikhowa soil No. 32	5·37	10·05	31·36	13·59	21·25	16·00	3·68	0·49	12·5	14·0	23·8	20·7	1·69
21	Woodbine No. 2	0·69	22·81	25·48	13·37	17·00	13 76	5·15	0·41	10·7	12·3	21·7	18·4	1·80
22	Budlabetta No. 6, B 9″	0·15	12·00	30·80	17·60	18·64	15·28	3·90	0·35	13·4	15 1	25·9	22·3	1·73
23	Soalkotie S. of Sessa No. 36 ...	0·37	22·57	29·44	11·42	16·56	14·38	5·52	0·56	11·3	13·4	22·8	19·7	1·82

Moisture values are calculated on dry soil.

TABLE III.

SILTS.

Showing Various Soil Fractions obtained by Sedimentation Process together with Moisture Values and Condition Factor.

No.	Soil.	Sol. in acid.	Coarse sand.	Fine sand.	Silt.	Fine silt.	Clay.	Loss on ignition.	Loss on ignition clay.	Moisture Values. Optimum. Water.	Moisture Values. Optimum. Ammonia.	Moisture Values. Puddle. Water.	Moisture Values. Puddle. Ammonia.	Condition Factor.
24	Dimakusi	2·19	0·83	26·04	40·55	11·80	13·37	5·31	0.47	14·1	16·1	28·6	26·5	1·39
25	Tondoo S. E. Dn. A. 1	0·03	3·65	30·32	33·22	23·49	5·52	3·28	0·09	15·2	16·9	38·2	33·1	1·37
26	Tondoo S. E. Dn. A 2 Subsoil ...	0 37	6·57	21·23	36·54	26·18	6·10	2·10	0·09	13·6	15·6	33.9	30·8	1·34
27	Chuapara	0·15	2·15	28·83	33·42	25·86	4·71	3·90	0·05	14.5	16·1	31·3	29·1	1·30
28	Dima Subsoil	0·76	nil.	61·56	27·66	7·94	0·61	0·93	nil.	9·2	10·7	31·3	24·3	1·62
29	Behora No. 15	0·58	10·66	18·45	25·25	19·56	11·73	2·79	0 05	9·8	10·3	19·4	15·9	1·71
30	Tursa (Jaigon) Sec. 1.	1·15	2·15	28·83	33·42	25·86	4·71	3·90	0·05	10·1	11·1	23·2	19·2	1·16
31	Tursa Surface Sec. 5.	1·10	6·24	29·65	19·87	26·65	12·07	5·05	0·18	14·8	16·4	27·2	26·2	1·26

Moisture values are calculated on dry soil.

TABLE IV.

CLAY SILTS.

Showing Various Soil Fractions obtained by Sedimentation Process together with Moisture Values and Condition Factor.

No.	Soil.	Sol. in acid.	Coarse sand.	Fine sand.	Silt.	Fine silt.	Clay.	Loss on ignition	Loss on ignition clay.	Moisture Values. Optimum. Water.	Moisture Values. Optimum. Ammonia.	Moisture Values. Puddle. Water.	Moisture Values. Puddle. Ammonia.	Condition Factor.
32	Dimakusi ...	0·70	1·38	14·19	31·62	22·94	21·96	6·38	0·62	17·8	19·8	35·3	32·2	1·41
33	Besakupi ...	0·42	6·10	13·68	19·01	26·75	30·27	4·95	2·24	19·9	23·1	33·9	30·7	1·84
34	Behora No. 5 Mikirchang ...	0·70	5·12	22·63	26·43	20·52	19·82	3·60	0·60	12·4	14·5	21·7	17·6	3·0
35	Behora No. 6 ...	0·74	6·67	20·93	27·98	21·30	17·77	3·63	0·34	10·6	12·1	21·3	17·2	2·09
36	Kurti, Dooars ...	1·30	10·53	7·81	13·66	21·41	37·33	9·73	4·64	22·2	24·3	35·4	31·0	1·97
37	Bhagotpore ...	0·95	10·44	14·62	15·44	21·18	27·90	9·57	1·37	19·9	21·9	35·6	32·5	1·47
38	Namrup No. 1 Topsoil ...	0·80	0·76	8·90	28·22	32·97	24·68	3·45	2·98	16·2	17·8	31·9	27·2	1·75
39	Hansara Soil No. 6, 24" ...	0·91	8·94	31·92	15·39	18·70	20·07	4·31	1·14	15·6	16·6	27·8	23·5	1·76
40	Samdang No. 9	0·23	6·83	28·63	12·88	23·96	23·16	4·26	0·65	14·2	15·9	23·9	20·9	1·94

Moisture values are calculated on dry soil.

TABLE V.

CLAYS.

Showing various Soil Fractions obtained by Sedimentation Process together with Moisture Values and Condition Factor.

No.	Soil.	Soil in acid.	Coarse sand.	Fine sand.	Silt.	Fine silt.	Clay.	Loss on ignition.	Loss on ignition clay.	Moisture Values. Optimum. Water.	Moisture Values. Optimum. Ammonia.	Moisture Values. Puddle. Water.	Moisture Values. Puddle. Ammonia.	Condition Factor.
41	Suffry ...	2·91	1·54	5·24	6·25	41·46	35·06	7·27	4·71	18·1	20·1	30·4	28·4	1·48
42	Binnaguri No. 7 of 5 ...	0·78	9·60	7·77	13·31	21·76	36·56	8·01	5·99	20·8	23·5	32·8	28·9	2·22
43	Binnaguri No. 4 of 10 ...	0·55	8·88	8·71	27·07	26·19	21·91	6·87	0·25	15·9	18·5	29·4	25·2	2·02
44	Nagrakata ...	1·19	5·45	6·89	15·04	21·71	38·67	10·46	6·20	20·0	22·2	32·9	28·6	2·02
45	Namrup No. 17 Topsoil ...	0·98	1·45	14·37	30·06	33·40	19·04	4·92	3·08	17·2	18·3	29·5	25·1	1·81
46	Namrup No. 1, bottom soil ...	8·93	0·41	5·05	22·63	32·31	25 26	4 80	2 13	18·8	20·9	31·4	26·1	2·42
47	Chalounie subsoil Engo. No. 8 ...	0·65	19·55	7·40	20·50	13·84	28 47	7·01	4·23	18·1	20·7	29·1	25·4	2·46
48	Borhat subsoil ...	1·57	nil	16·17	23·71	27·73	25·43	5·15	3·32	19·4	20·9	34·3	30 2	2·14
49	Hantapara ...	0·95	4·81	5·96	17·63	43·02	21 53	5·57	0·10	21·3	23·4	36·6	33·6	1·50
50	Hilla ...	0·47	6·75	5·33	29·98	26·29	23·64	6·28	0·25	15·7	18·8	27·1	24·0	2·21

Moisture values are calculated on dry soil

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NOTES.

Mites in Tea-Seed.—An interesting note on the discovery, in Java, of mites in tea-seed imported from British India appears in the first number of "De Thee" for 1921.

The author of the note (R. Menzel) records that on opening "floaters" many of them were found to be full of a reddish-brown dust swarming with small mites of the genus *Tyroglyphus* (to which belongs the cheese mite). He gives the following table showing the percentages of affected seed obtained from six parcels examined, from which it will be seen that in one case as much as half of the seed was damaged.

No. of seeds tested.	No. infested with mites.	Percentage infested.
733	58	8
40	4	10
85	8	10
151	50	33
28	11	40
113	58	50

The author draws attention to the fact that since the mite possesses no special breathing organs, it is not possible to deal with it by fumigating the seed. The mite can be killed by heating to 122°F but this method often destroys the germinating power of the seed, so that it is not practicable.

These mites spread by attaching themselves to flies, mice, etc., in the young stages. It is therefore highly probable that infestation occurs while the seed remains stored in godowns or fermenting rooms during the period between the commencement of harvesting and the despatch of the crop.

The author refers to the desirability of giving attention to this matter in the packing sheds from which the seed is despatched, and although the matter is apparently not regarded in Java as very

pressing, and although the possibility of the occurrence of the mite in the Dutch East Indies is admitted, it would indeed seem to be highly desirable that exporters of tea seed from India should arrange that seed intended for export be stored, while on the factory, in rat and fly-proof bins. Such bins could be easily and inexpensively constructed, would reduce the risk of infection to a minimum, and enable suppliers to guarantee that every precaution has been taken to prevent infection.

E. A. A.

RAINS CULTIVATION

BY

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From the earliest days of man's history agriculture has been pursued and in the course of many centuries much practical knowledge has been accumulated, but it has been only in comparatively recent times that it has become recognised that the natural sciences can assist the Agriculturist towards a better appreciation of the problems confronting him. Agriculture in the past has been a method of the rule of thumb and improvements have been effected only by a very slow process. Science has now, however, been commandeered to assist in its development and perhaps one of its primary duties at the present time is not to alter agricultural methods so much as to explain the reason for performing the common operations. The experience of the ages has taught men the necessity of cultivating the soil if crops are to be grown and as a consequence of this certain principles have become recognised, but it is not always fully appreciated how best to adapt such general principles to the particular conditions of soil, climate, etc. It is with the object of helping towards the better understanding of the effect of some of the operations of cultivation that this article is written so that men shall be in a better position to adapt the general principle to their own particular needs. It is not intended to enter into a discussion of the whole question of cultivation but as the title of the article suggests into only one aspect of it, namely, cultivation in the rains.

In respect to cultivation in the rains our opinion in general terms may be expressed as follows :—Hoeing in the rains generally does more harm than good. When it is considered that a large proportion of the increase of tea crop in the past 15 years or so has been due to cultivation, the above expressed opinion requires

explanation and it becomes necessary to examine in more detail the effects of cultivation as carried out in the operation of hoeing during the rains. What are the benefits that are expected to arise from hoeing? These can be briefly summarised under three headings :—

(1) The keeping down of jungle :

(2) Increased availability of food to the bush :

(3) A better physical condition or state of tilth in the soil.

The increased availability of food to the bush is of course largely dependent upon the physical condition of the soil ; and improved tilth includes amongst other things better aeration of the soil.

Jungle undoubtedly does harm to the tea among which it grows. It becomes a competitor for food and water and also any plant growing in the neighbourhood of another plant exerts a poisonous effect upon it. Undoubtedly the main benefit that has been derived from hoeing in the rains has been from the removal of jungle.

The effect of hoeing on the physical state of the soil has not always been good. When the soil is too wet, not only does it produce no improvement, but actually spoils the existing tilth. Very fortunately, hoeing does not exercise the same sheering effect as does ploughing, and ordinary light hoeing in the rains generally amounts to little more than cutting through the roots of the jungle at a very shallow depth below the surface. Further the very presence of the jungle tends to minimise the puddling effect which ruins tilth.

Loss of tilth from rains hoeing has therefore been slow, particularly as the drying of the soil during each cold weather acts in the opposite direction and restores at least a great part of the lost tilth.

Probably even more serious than the effect of the hoeing itself has been the effect of heavy rain beating on an unprotected surface of clean loose soil.

Not only does this beating directly puddle the soil and leave a most unpleasant 'skin' on the surface (insufficiently pervious to water and air), but the finer soil particles are washed down, leaving the surface much more sandy indeed, but tending to 'pan' the soil at a little below the cultivation depth, thereby greatly interfering with the efficiency of the drainage.

After many years the bad effect of hoeing wet soil, and of leaving clean soil exposed to the rain, has become apparent on many soils.

In a soil in good tilth the very small sticky colloidal clay particles join together to form a smaller number of large particles or aggregates, and thus the soil loses much of its clayey nature ; it becomes less sticky and the increased size of the various interspaces between the aggregates allows a freer movement of air and water. The puddling effect of hoeing in the rains causes these aggregates to break down, the soil becomes more sticky, less pervious to water, and more inefficiently aerated. These physical effects cause changes in chemical and biological reactions in the soil. The soil acidity increases, nitrification becomes slower, and plant foods generally become less available and in extreme cases actually are lost altogether.

Since puddling affects the clay particles of a soil, the effect of rains hoeing is seen at its worst on soils of a high clay content. All fertile soils, however, contain some clay and therefore the effect is produced on all soils though to different degrees. Sandy soils containing little clay may be so little affected, that the effect is completely reversed at the next drying so that no permanent harm results ; and there are a few extremely sandy tea soils so deficient in the colloid particles which 'bind' a soil, that puddling of the very small quantity of clay present, may actually be beneficial.

With the exception of these sands however, it is clear that hoeing during the rains would be better avoided.

During dry periods when breaks in the rains occur, hoeing often becomes possible and as much should be done then as is practicable. Good drainage is at such times of very great

assistance since it will permit of hoeing to be commenced sooner and the time increased during which hoeing will do good and not harm.

To the cessation of hoeing during the rains there are two great objections.

The first is that hoeing is hard exercise, and a labour force soon gets out of training if hoeing is dropped, so that when hoeing is resumed the men get sore hands, and their unused muscles cannot do the work which they performed with ease when in condition. In some cases the men actually become unwell, from the loss of the exercise to which they had become accustomed.

Objections have also been made that a garden cannot afford to pay labour to sit in the lines and do nothing. Since it is clearly better to pay men to do nothing than to pay them to do harm, this objection has little force.

However it is necessary to provide alternative work. On many gardens all the labour available can be used for plucking; while methods of keeping down jungle other than hoeing (which will be dealt with later) also, of course, use labour, but neither of these will keep the men in condition and it is advisable to provide as much work as possible, which involves the swinging of a hoe.

When the soil is wet the digging of drains, and the deepening and cleaning of old ones is very much easier than in the cold weather. The area of which the tilth is thus spoiled is in any case small, while if the excavated soil is left heaped up until the cold weather, it will be subjected to that alternate wetting and drying which rapidly produces a state of good tilth.

Trenching is also easy work during the rains and it would be of great advantage to get in crops like Arhar before they get too woody. In this case, however, some care would be necessary. The filling in of the trenches should be left till a time when the soil is not too wet, otherwise the puddling effect may be serious. In the cold weather trenches should be filled in as soon as possible to avoid undue drying out of the soil. In the rains, trenches could be left open with good effect. Trenching, however, could be

done in the rains only on a small scale. From good yielding tea, the cutting of the root ends would decrease the flush for the remainder of the season. In young tea, however, and in cases where the state of the tea warrants some sacrifice of present crop for the sake of future yield, trenching in the rains is strongly recommended as an alternative to hoeing, provided that the filling in of the trenches be done when the soil is not so wet as to puddle on working.

Assuming that a manager can so arrange his work that the men can be fully and satisfactorily employed during the rains without hoeing work, there still remains the serious problem of keeping down the jungle.

Without any doubt the presence of much jungle produces serious loss of crop, and during the rains, the jungle is growing very rapidly indeed.

If we examine the factors which make up the harmful effect of jungle on tea,—competition for water, competition for food, and toxic effect on neighbouring bushes—it is at once clear that the most serious factor of competition for water is not active at all at the times when it is recommended that hoeing shall not be done. The soil has then too much water, and it is therefore obvious that there is more than enough water present for tea and jungle both.

A full explanation of the last factor (of toxicity) is not yet agreed upon. It is very probably due to the presence of too great a concentration of carbon dioxide, and to a corresponding deficiency of oxygen in the soil. Rain water falling on, and percolating through a well drained soil carries with it dissolved oxygen from the air and keeps the soil thoroughly well aerated, while excess carbon dioxide (or other soluble toxin if there be any) is at the same time washed out. The toxic action of jungle then is also at its minimum during the rains.

The only bad effect of jungle which is active in the rains is the competition for food, and this of course may be serious. The loss of food by washing out however is also very serious and such loss is permanent. The presence of some jungle will minimise this loss by washing and such food as is taken up by the jungle is always returned to the soil when the jungle decomposes after

being buried. The buried jungle also supplies to the soil organic matter which has very largely been obtained from the air.

The jungle thus acts as a "catch crop." The term "catch crop" is used in general agriculture to mean a crop specially planted when in the ordinary rotation the soil would otherwise be fallow. The special function of the catch crop is to take up the soluble plant foods (nitrates forming the most important part), which would otherwise be washed out and lost.

When it is remembered also that the presence of jungle not only prevents the puddling of the surface of the soil by rain, but actually by its root action improves the tilth of the soil, it will be clear that the presence of some jungle may not be altogether a bad thing on soils where the tea does not cover the ground.

If the tea completely covers the ground it of course provides all of these advantages for itself. It will not allow the beating of unprotected soil by rain, its roots will very thoroughly explore all the available soil and so reduce the loss of soluble food, and by its prunings it will maintain the organic matter content of the soil. In addition it will keep down jungle for itself; for jungle will not grow in thick shade. A good food supply will of course be necessary either from a naturally very rich soil, or from manuring.

There are in the Surma Valley rich clay flats giving over 20 mds. of tea per acre which are either never cultivated or get no more than two or three scrapings in a year. The soil is absolutely free of jungle and is in beautiful tilth. They would gain in improved aeration and gain greater efficiency from buried prunings, if a cold-weather hoe could be given, but in a place as described a hoe cannot be swung, and where any cultivation at all is given, it amounts to little more than scratching the soil with a hoe pushed under the branches. Yet with no cultivation (or practically none) the soils are in beautiful tilth. Many regularly well-hoed soils are very bad in comparison.

These rich clay flats are here interesting, firstly because they demonstrate that tilth may be maintained without hoeing, and secondly because they suggest a means of minimising the necessity of hoeing to keep down jungle.

Where the tea itself does not cover the ground (as is the usual case, even though outside branches are frequently lightly touching) the use of shade will assist very effectively to keep down jungle, and will also provide the advantages of a catch crop to greater or less extent.

The low growing leguminous plants usually used as green manures perform the functions of a catch crop perfectly, particularly having regard to the time of sowing—March to May. It is at this time that nitrate formation is likely to have reached a maximum, and loss of nitrates by washing out is therefore prevented over a critical period. The green crop also kills out jungle by its very denseness and ability to grow rapidly. The growth of a crop like cowpeas is very strongly advised where there is much jungle of a particularly undesirable nature, like thatch grass.

More effective shade can be provided by a taller crop like Dhaincha or over a greater part of the season by semi-permanent crops like Arhar or Boga medeloa. When these latter are planted as hedges between every second or third row of tea a greatly reduced jungle growth is obtained.

Shade trees also contribute to the same effect. One does not see serious trouble from thatch grass or other deep rooted and tall grasses under shade trees, but plants like Ageratum (Ilami, cold weather weed) or shallow-rooted, low-growing grasses which do little harm become established.

The tea bushes, like the jungle, might be expected to suffer from the shade effect. Tea however is one of the plants actually benefited by light shade, although an amount of shade which keeps down jungle altogether would certainly do harm to the tea.

It is clear then that green crops and shade trees may be used to reduce the necessity for cultivation in the rains, but of course it is not expected that green manures and shade trees can be grown all over a garden at once.

It has already been pointed out that a light covering of jungle, during the rains, is preferable to absolutely bare soil ; but deep-rooted and tall jungle must never be allowed to become established

nor should even better types of jungle be allowed to become excessive.

On the greater part of the area of most gardens direct methods will have to be adopted to keep down jungle. It is the main object of this article to insist that hoeing should be pushed on as rapidly as possible whenever the soil is not too wet, but that other methods should be adopted whenever it is clear that hoeing would puddle the soil. At the same time it is not desired to establish an absolute rule that no hoeing must be done in the rains. Where bad types of jungle like thatch are prevalent the damage done by it may be more than would be done by a single hoe in the rains. Still, even then the hoeing need not be done when it is actually raining.

Bearing in mind the principles which have to be considered the Manager's discretion will have to be used.

Alternatives which are preferred to hoeing are hand forking and sickling which should be used in combination.

The forking will aim at establishing a circle, of about 3 feet diameter around the bush, which is absolutely clean weeded. Within this circle jungle will hardly get a start since it is well covered by the bush, and this clean surface will provide free exchange of gases between soil atmosphere and the air above, thus ensuring aeration of the soil around the bush.

This forking will naturally be much better applied when the soil is near its optimum water content, but when the soil is wet it can be made rather a pulling out of weeds by hand assisted by the fork, than an actual working of the soil.

The jungle between the lines may be left to grow to some height without any great loss to the tea (at times when there is water enough for both), and whenever it is considered excessive it may be sickled by hand. A proper application of forking and sickling should at least reduce the necessity for hoeing to a minimum.

It may be pointed out that all these methods of doing without hoeing during the rains will be particularly valuable on slopes

and teelas where cultivation not only ruins tilth but leads to greatly increased loss of soil by wash. In these situations the very best cover crop is the tea bush itself. Teelas and slopes should therefore be close-planted and kept continually infilled.

SUMMARY.

1. Hoeing a wet soil ruins the tilth.
2. In the rains the soil is generally too wet, and therefore hoeing in the rains should be avoided.
3. Unless cultivated, soils will grow jungle, which in excess is harmful.
4. In dry intervals hoeing improves tilth, and hoeing should then be carried on as rapidly as possible.
5. This alone will not generally keep down jungle sufficiently ; but rather than spoil tilth by hoeing wet soil, hand-forking and sickling should be used.
6. Green manure crops greatly assist to reduce jungle.
7. Shade greatly reduces jungle growth. It may be provided by tall green manure crops like Arhar, by shade trees, or the tea bush itself. If grown to cover the ground thickly and completely no jungle at all will grow under tea, and in that case hoeing may be dispensed with all together, except when the soil is at its optimum water content.
8. The hoeing men who by dropping hoeing may be left unemployed may be used for draining, trenching, hand-forking, and sickling.

METEOROLOGICAL OBSERVATIONS IN ASSAM.

C. R. Harler, B. Sc., A. I. C.

Introduction.

Generally speaking there are two sets of factors affecting the tea crop in North-East India—weather and soil condition. The type of bush, the method of pruning and plucking are secondary factors. It is possible to influence profoundly the soil condition not only by drainage and cultivation by also by the use of fertilizers and manures. The weather is beyond our influence and, so far, meteorology in Assam has been so little studied that we are even unable to predict the weather with any degree of certainty. True there is not the necessity in Assam that is felt in colder climates where the prediction of a frost is of great service to cultivators. It may also be argued that the tea bush is a perennial and that a close study of the weather cannot lead to any direct improvement of crop outturn This view is incorrect.

The importance of meteorological observations and the necessity for opening stations at critical intervals over a country has been recognised by Azzi (1) and his work has been taken up and modified by Carton (4) in connection with agriculture in Indo-China.

Azzi, by studying the relationship between the plant and the climate and the plant and the soil hopes to develop the science of agricultural geography. This science will consider the distribution of plants not as static but as dynamic systems in that they are functions of the medium in which they, the plants, live. The science thus becomes essentially biological and more especially a branch of the science of ecology.

Before studying the tea crop with regard to climatic conditions in any special year it is instructive to follow the growth periods of the tea bush. With annual crops there is a ***critical period*** following sowing during which certain conditions must hold if the crop is to be successful. This period interests the tea planter so far as nurseries and green crops are concerned. With regard to the fully grown bush, the months of March, April and May following on the cold weather drought are critical, and during

this period unless rain falls the bushes are seriously affected. When a bush is collar-pruned this period becomes still more critical and for this reason heavy pruning should be carried out as early as possible so as to minimise the effect of a drought.

In February the bushes begin to come away in normal years and during the next two months they are "tipped." A shoot which is plucked in March or April gives rise, on a straight flush, to six shoots corresponding to the monthly flushes in May, June, July, August, September and October. Ten years ago only five flushes could be recognised and the addition of an extra flush is due, no doubt, to improved methods and treatment. A close study of the meteorological conditions enables us to accurately foretell these flushing periods.

From the above it is obvious that the weight of the crop given by the "tipping" influences the total crop although the number or shoots may be made up on the May or later flushes. When the bushes are growing vigorously shoots are produced from more than one axil and the total number of shoots from one original tip may reach ten or twelve during the season. These extra shoots mature at periods different from the flush and may partly mask the latter. On this account a weekly crop can be obtained.

THE MONSOON IN ASSAM DURING 1921.

In Assam, the monsoon, as denoted by rainfall, is not so well defined as in Bengal. The early rains often run on till the true monsoon breaks. This was particularly the case in 1921.

Below is shown the rainfall recorded at Tocklai during the past 4 years together with the calculated degree of wetness for each month. It is obvious that the total rainfall over a certain period does not signify so much as the distribution of rain over the same period. Half an inch of rain in the middle of a wet spell has as much effect on a soil as two or three inches during the same spell. The degree of wetness is calculated as follows :—

$$\frac{\text{Rainfall} \times \text{No. of wet days.}}{\text{No. of days in month.}}$$

The significance of the degree of wetness may here be considered. Taken over a long enough period this factor would show little variation. So far as the tea crop is concerned the interval between successive flushes would be a more suitable period for considering the degree of wetness. Thus in 1919 a dry period commenced towards the end of July and continued throughout August so that the flush was quite obliterated. Yet the degree of wetness for July does not appear to be deficient. By taking the degree of wetness over a shorter period, as yet unfixed owing to insufficient observations, a much nearer correlation between rainfall and crop could be obtained.

Another factor to be considered in connection with the degree of wetness is that of temperature. An inch of rain early in the season or in October has as much effect on the soil as a much greater fall in the hotter months. In October 1921 when the degree of wetness was 2·66, the soil was as moist as during the previous month when this factor was 9·49, but the temperature much higher.

The degree of wetness as calculated below may only be taken as a first approximation to a measure of rainfall effect.

The distribution in 1921 compared with other years was particularly favourable until November during which month no rain fell. On account of this early close the crop suffered severely.

Table showing Monthly Rainfall and Degree of Wetness at Tocklai.

Months.	Rainfall in inches.				Degree of wetness.			
	1918.	1919.	1920.	1921.	1918.	1919.	1920.	1921.
January	0·12	0·28	0·63	1·63	0·004	0·02	0·04	0·42
February	1·26	0·97	2·73	0·86	0·18	0·17	0·87	0·21
March	6·37	0·75	6·15	4·21	3·29	0·07	2·97	1·22
April	5·91	7·41	9·08	14·03	2·16	1·91	3·60	10·29
May	15·42	6·57	6·73	9·28	6·96	2·54	2·38	5·08
June	14·92	22·09	9·89	7·71	8·61	12·51	6·59	6·42
July	18·20	16·37	14·18	14·52	11·77	10·56	8·46	9·84
August	19·48	10·71	9·22	9·71	11·31	4·42	5·94	6·57
September	12·44	9·59	6·17	14·23	6·22	5·75	3·08	9·49
October	2·42	9·40	2·47	5·15	0·31	3·33	0·72	2·66
November	0·40	0·40	0·40	nil	0·13	0·56	0·26	0
December	nil	0·11	0·13	1·14	0	0·01	0·01	0·11
Total	96·94	75·08	67·55	82·47				

The prevailing wind in the Assam Valley during the monsoon is South-West. During the cold season it is North to North-East. All the monsoon rain is brought originally from the South either round the Garo Hills or by way of the Jetinga Valley. The former wind usually strikes the Tezpur district and is then reflected to the South bank of the river where it impinges against the Naga Hills somewhere about Moriani. In this manner, Tocklai just escapes the rain whilst precipitation takes place along the lower ranges of the Naga Hilla a few miles away. At night, however, the wind which blows from the hills to the plains deflects the moist wind from its general direction Numaligarh-Nakachari and it is then that Tocklai receives most of its rain. The hotter the day the earlier is the evening precipitation. The total rainfall at Tocklai is about the same as that under the Naga Hills.

The wind which blows up the Jetinga Valley precipitates rain evenly up the Assam Valley. The area below Golaghat receives most of its rain from this source and very little from the other source. Thus the rainfall at Nowgong is only about 60 inches, which is about the limit below which tea will not grow luxuriantly.

During the rains heavy rainfall is naturally accompanied by a fall in temperature, but before the monsoon has broken the opposite is noticed. This is because the rain-bearing wind originates in the South, although it has often moved round the hills which surround the Valley, so that it appears to blow from the North.

Vapour Pressure and Temperature Considerations.

The atmospheric vapour is one of the chief climatic factors influencing the tea crop in North-East India. The relative humidity varies from about 80 to 95, but the vapour tension varies to a much greater extent.

The vapour tension of the atmosphere is a measure of the total atmospheric moisture. Although the monsoon as denoted by rainfall is not very well marked in Assam, it can easily be followed by the vapour tension curve. Generally speaking, monsoon conditions exist from the end of May to the end of September. During this period the pressure from the Bay of Bengal is

continuous and the Brahmaputra Valley receives a steady inflow of moist air. This is clearly shown on the curve below.

In addition to this, the whole of Assam during the rains resembles a great lake supplying an unlimited amount of moisture to the atmosphere. In spite of this the day is never long enough to bring about complete saturation of the atmosphere—about 75% saturation is usual. At night when the temperature drops to the neighbourhood of 80°F saturation and precipitation as dew occurs. A hot day greatly increases the vapour pressure, and the following night is insufficient for complete precipitation of the vapour in excess of saturation. In this manner the vapour pressure will follow mainly the daily temperature, for the night temperature, as will be seen from the curve, is fairly constant and does not vary nearly so much as the maximum temperature.

The effect of temperature and vapour pressure on the tea crop will now be considered.

The transpiration rate of a bush has a great deal to do with the rate of growth, for if transpiration is rendered difficult then the bush grows more leaves in order to carry on the process. Transpiration is a vital process and is dependent chiefly on the temperature. Sewell Wright (7) dealing with the rate of transpiration of leaves mentioned in the researches of Briggs and Shantz (3) gives the following correlation between rate of transpiration of leaves and meteorological conditions :—

$$d_t = 0{\cdot}55,\ d_h = 0{\cdot}18,\ d_w = 0{\cdot}09,\ d_r = 0{\cdot}04$$

and for evaparation from a shallow tank—

$$d_t = 0{\cdot}30,\ d_h = 0{\cdot}19,\ d_w = 0{\cdot}16,\ d_r = 0{\cdot}16$$

where d_t represents the degree of correlation between temperature and transpiration or evaporation, d_h the degree of correlation for humidity, d_w that for wind and d_r that for radiation.

It may here be mentioned that the degree of correlation between two factors is a measure of the dependence of one factor on another. Thus if $d_t = 1{\cdot}0$ this would signify that evaporation is wholly governed by temperature. It will be observed that the sum

of the correlation factors falls short of unity and this deficiency is a measure of the outstanding, unconsidered factors.

The four factors are much more nearly equal in importance in the case of evaporation than in the case of transpiration. The influence of temperature is seen to be in the latter case much greater than that of the other factors, and about three times as great as that of humidity.

During the monsoon the difference between the maximum and minimum temperatures in Assam is only about 10°F. In the cold season this difference is about 20°F, the low night temperatures accounting chiefly for the increased difference. It is undoubtedly this difference which stops the flush during the cold season. The period when humidity is usually most deficient is during October when the vapour pressure falls at a much greater rate than temperature. In seasons when this deficiency does not occur, October is often the best month for crop. Towards the end of the year a state of saturation exists every night, and in this respect monsoon conditions are realised although the temperature is much too low for the bushes to flush vigorously.

Observations made at Heeleaka (5) some years ago showed that the tea crop, with certain exceptions, closely followed the temperature.

Thus when the temperature rises abnormally, the crop goes down. This depression, however, will cease as soon as vapour pressure conditions approach equilibrium and it is not likely to occur if the temperature rises slowly day by day, for then the atmosphere never becomes excessively dry. A period of low temperature resulting from copious rainfall also depresses the crop. In this case there is no deficiency in humidity, and temperature is the sole cause, not considering soil condition, of crop depression.

Studying the rate of growth of plants Briggs, Kidd and West (2) have come to the conclusion that temperature is the chief factor influencing crop.

Livingstone and Livingstone (6) correlate the rate of growth of plants with temperature and show it to follow Van't Hoff's law

for general chemical reactions. Thus for every 18°F rise in temperature the rate of growth will be doubled. During the fastest growing period—August and September—the mean daily temperature is about 83°F. At the end of October the mean has fallen to about 74°F which difference accounts for the delay in the Autumn flush.

Pot culture experiments carried out at Tocklai during the past two years have yielded interesting results. The relationship between temperature, humidity and rate of transpiration has been observed and correlated with the observations of other workers made on different plants. It has also been noticed that the rate of transpiration is an index of the health of the plant. When transpiration decreases, wilting or blight attack, not evident at the time, follows in a few days.

Observations show that the ideal tea weather is, maximum temperature about 92°F, minimum temperature, accompanied by saturation, about 82°F. These values naturally vary with other factors like wind and radiation.

It seems probable that humidity affects the *amount* of growth rather than the *rate* of growth which depends more on the temperature. Thus a high humidity might force two shoots instead of one but a high temperature would bring about rapid growth of these shoots.

The wind and the radiation factors have not been studied in any detail. Ordinarily the wind, if hot, is moist. In February 1919, however, a hot dry wind blew for some days with the result that the leaves wilted and many bushes were left almost bare. Under normal conditions these factors are seen from the correlations above to be insignificant compared with temperature and humidity.

Reverting now to the question of autumn quality in teas it is interesting to consider how this is affected by climate. It is generally understood that the slower rate of growth of the late flushes has a great effect on quality. Reed (7) studying the cell sap of young fruit trees discovered that the concentration

decreased as the rate of growth increased and also that it increased as the season advanced. He also discovered that the concentration of cell sap with heavily pruned trees is less than that of others. This is due to the quicker growth which comes with heavy pruning. The cell sap is most concentrated in the tip of the leaf. All these observations may well apply to tea and it seems highly probable that cell sap has a great deal to do with tea quality.

It has been noticed that the addition of water to the soil reduces the concentration of the cell sap. If cell sap concentration is connected with quality, then the moist condition of the soil in July and August will have much to do with the poor quality teas of these months.

In accordance with generally accepted ideas it has been shown (5) that the amount of dry matter in the leaf throughout the season varies inversely as the amount of leaf grown.

Another factor, and one of great importance, is the effect of atmospheric conditions on manufacture. It was pointed out on page 15 that during the latter part of the season the vapour pressure of the atmosphere falls at a greater rate than the temperature. Thus all through the monsoon the atmosphere is nightly saturated. This state of affairs first became definite in 1921 on June 20th. From September 16th to November 16th, the atmosphere was not saturated at night although after the latter date it was so. During this dry period a good wither is possible.

On page 14 are given two sets of factors correlating the transpiration of leaves and the evaporation of water with climatic conditions. During the earlier part of the withering process of the tea leaf drying takes place according to the former set of factors for the leaf is still alive and is wilting. As the leaf gets drier the vital actions going on in the leaf cells give place to physical actions and the drying then follows the second set of factors. The leaf is now truly withering. During the wet season, leaves at the end of an 18-hour wither still contain about 70% moisture—a decrease of 5% on the moisture in the fresh leaf—whereas during the autumn the moisture falls to 60%. This difference denotes a profound alteration in the vitality of the leaf and is probably

followed by equally important differences in the chemical actions going on in the leaf.

Autumn quality is the product of the factory no less than the product of the bush.

The Soil Condition.

The soil condition includes moisture content, aeration, tilth, temperature and many other more complicated factors. The main question is soil moisture and here is one of the chief problems of the tea planter. It is a difficult problem to drain sufficiently to carry away 100-- 200 inches of rain precipitated during six months and to conserve the few inches which fall during the remainder of the year.

The late autumn rain can be fairly well conserved by the mulch left after the end of the season's deep hoe. A mulch, however, acts in two ways and may prevent the small quantity of rain falling at Christmas time from entering the soil.

The greater trouble is an overmoist soil. The maximum and cumulative effect of this factor is seen in August when a great crop depression is noticed. Such instances were observed in 1920 and 1921.

During the year under consideration the moisture was estimated daily on the Tocklai Clearance. The soil is a silty sand with an optimum water content of about 14%. Early in April the moisture content rose to 18% and till the middle of November it kept above 18% except on one or two occasions. Thus in the middle of May and towards the end of July the soil dried to some extent. These instances naturally fit in with a falling off in rainfall.

During the rains a certain amount of hoeing must be carried out and from such work increased crop results, but the tilth of the soil is often damaged. In some cases where hoeing is done during the rains the clods appear like bricks and for all practical purposes are no longer a part of the soil as a medium for supplying plant food. In such cases the increase in crop is due to the removal of jungle and partial aeration. In the Surma Valley it

happens in some cases that the spread of the bushes shuts out the light from the soil, and jungle cannot grow. Even in these cases, forking results in an increase of crop. Here the increase is due wholly to aeration.

The effect of very heavy rain is interesting. Thus 7 inches during the rains have no more effect on the soil moisture than one inch or so. Although the water holding capacity of Tocklai soil is about 40%, the moisture content seldom gets above 21%.

The Tea Crop in 1921.

On the curve is shown the tea crop, in lbs. green leaf, for the Tocklai Clearance—an area of 3½ acres. The tea on this area was put out in 1914 and consists of half acre blocks of Burma, Kalline, China, Kharikatia, Singlo, Panighat and Betjan bushes.

The 1921 season was normal, so far as the tea crop was concerned, until the end of October. The failure of the rainfall in November accounted for the short crop. The season on the whole was a very wet one and this made for good wood.

There are, as has been mentioned elsewhere, usually six flushes in a season, but these naturally cannot be correlated with any particular variation in the weather. The flush may be hastened or delayed by a few days and the size of the flush may vary. The maximum effect of any weather peculiarity is evident about three weeks after such weather.

The May flush in 1921 was fairly late (about 10 days later than in previous years) owing to the abnormally wet April. It was however a big flush and spread over two weeks and was greatly helped on by the hot fortnight ending May 8th.

The June flush was similarly late not only following on the previous flush but owing to the cool three weeks ending June 5th.

The July flush followed quickly on the June flush although during the actual time of plucking there was a considerable fall in temperature. The depression which followed has often been observed.

A phenomenon which is likely to occur, especially about midway through the season, is *banjhi*-ness when the shoot becomes dormant. The exact significance of this state is not yet understood, for although a bud may be *banjhi*, the first and second leaves may be growing with great vigour. It was at one time thought that the *banjhi* state denoted complete equilibrium between the amount of food taken in by the roots and the amount necessary for the bush to function. The fact that a change in the weather, such as a break in the rain or the end of a drought, or the disturbance of soil conditions by cultivation ends a period of *banjhi*-ness, supports this idea. But the fact that individual branches become *banjhi* and that *banjhi*-ness is confined to the growing point of a shoot suggests that the cause is more complicated.

The August flush extended over two weeks. By the end of September the total rainfall was well above the average, which pointed to an early close to the season. The Autumn flush extended over 3 weeks. Its heaviness was due partly to big leaf which resulted from the delay of a few days between the August and September flushes and partly due to the round of hoeing put in during a dry spell towards the end of July. Previous to this, the jungle had become very thick.

Early in October the wind turned to the North, the rain tailed off and the temperature and humidity fell so sharply that all chances of a November flush vanished.

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EXPERIMENTS ON THE MANURING OF GREEN CROPS.

(Season 1921)

BY

H. H. Wiles, M.A.

This series of experiments has now been in progress for four consecutive years, and the results obtained during 1921, while they amplify and to a large extent confirm those obtained in previous years, are also of quite exceptional interest in themselves by reason of the enormous percentage increase shown by all the manured plots over the check plots.

In last year's article on this subject Cooper (1) remarks :—" The residual effects are very great and it is clear that a single application of certain manures has effected an increase in fertility which will extend over many years."

This year's results have confirmed both the statement and the prophesy, and though it would not perhaps be true, in view of the somewhat smaller crops obtained on most of the plots during 1921, to say that the residual effects are greater than they were last year, it can be definitely stated that all the manures applied have produced a very marked increase in fertility, which, in several cases, show signs rather of increasing than decreasing in this the fourth year after application.

The following table gives crop records of the various plots during the past four years :

* For previous articles see *Quarterly Journal*, 1918, Part IV (page 106) and 1920, Part II (page 48).

MANURING	lbs. per acre.	Plots.	Crop in tons per acre.			
			1918	1919	1920	1921
Check		3	2·83	·82	·97	·16
Slaked lime	800	2	2·43	1·14	1·99	1·73
Crushed limestone	1200	1				
Slaked lime Sulphate of Ammonia	800 150	2	3·09	1·49	2·04	2·32
Crushed limestone Sulphate of Ammonia	1200 150	1				
Carbonate Magnesia Sulphate of Ammonia	900 150	2	3·34	1·39	1·89	1·15
Salked lime Sulphate of Ammonia Sulphate of Potash	800 150 75	2	3·26	1·62	2·31	2·14
Crushed limestone Sulphate of Ammonia Sulphate of Potash	1200 150 75	1				
Slaked lime Sulphate of Ammonia SULPHATE OF POTASH	800 150 8200	2	0·49	1·83	3·55	3·31
Crushed limestone Sulphate of Ammonia SULPHATE OF POTASH	1200 150 8200	1				
Slaked lime Nitrate of Potash	800 50	2	2·70	1·28	2·03	1·89
Slaked lime NITRATE OF POTASH	800 2500	1	2·64	2·53	3 10	3·04
Slaked lime Sulphate of Ammonia Superphosphate	800 150 150	2	4·23	1·48	2·44	1·68
Crushed limestone Sulphate of Ammonia Superphosphate	1200 150 150	1				
Slaked lime Sulphate of Ammonia SUPERPHOSPHATE	800 150 8200	2	4·05	2·70	3·56	2·85
Crushed limestone Sulphate of Ammonia SUPERPHOSPHATE	1200 150 8200	1				

NOTE :—The area of each plot is approximately 1/50th of an acre.

It will at once be noticed from the above table that this year's crop shows a decrease from last year, although only a comparatively small one; the average being 2·03 tons per acre as against 2·39 in 1920.

While this decrease is only what one might naturally expect, owing to the gradual lessening of the effect of the manures together with the loss of a certain amount of fertility by the soil, due to the complete removal of the crops annually for three years, it is probably actually due in a far greater measure to the unfavourable weather conditions prevailing at the most critical period in the growth of the crop.

The crop (Vigna Catiang) was sown on April 18th, excellent brown imported seed being used, and it was originally intended to grow it for six weeks only, as in previous years. The seed germinated quickly and the young seedlings at first came up well, the weather during the first fortnight after sowing being very favourable. During almost the whole of May, however, which should normally have been the principal period of growth, conditions were bad owing to excessive bright sunlight, dry winds and no rain, and growth was almost entirely checked. Indeed the majority of the plants were so backward at the end of six weeks that it was decided to leave them in the ground for another month. However, favourable conditions set in during the last few days of May, and continued throughout June with the result that the plants began to flower on the phosphate plots after nine weeks in the ground, and the crops from all plots were accordingly pulled up and weighed on June 22nd.

Another point to be taken into consideration in comparing the figures for 1921 on the above table with those for previous years, is that whereas the latter represent actual yields, this year's figures have had to be calculated, owing to the planting, in January 1921 of two lines of tea in each plot, which necessitated a different method of sowing the green crop.

The reason for planting these plots with tea is to ascertain whether the manures applied will produce an effect on the tea

similar to, or different from, that produced on green crops ; and, if the former, to what extent the results are directly comparable.

The cowpeas in this instance were sown in three strips per plot, between and on each side of the tea, each strip being composed of four rows with seeds 3″ apart in the rows. The actual number of seeds sown per plot was therefore known, and a correcting factor has been applied in order to convert the actual crop results obtained to one which can be directly compared with the broadcast sowings of previous years.

Comparing the 1921 crops with 1920, the greatest decrease, apart from the check plots has occurred on the plots receiving Superphosphate, of which both large and small dressings show a loss of about ¾ of a ton per acre, the figures being approximately the same in each case as in 1919, which was also a bad crop year. This loss is probably partly due to the fact that these plots alone were past maturity when gathered.

As noted by Cooper (2) last year, the crops on these plots come early to maturity and those on the plots which received the heavy dressings were the only ones fit to be gathered at the end of six weeks. By the time they were pulled up, they were in full bloom, while a few plants here and there had even seeded, and there was considerable yellowing and leaf-fall apparent.

Disregarding for the moment the Superphosphate plots, the check plots again show by far the heaviest loss (0·81 ton per acre) followed by the plots receiving Magnesium Carbonate, the yield from which has decreased by 0·74 tons per acre.

So far as the check plots are concerned, these figures support the theory that where no manures have been applied rapid soil-deterioration has already taken place, as a result of continued cultivation and removal of the crops grown.

The marked superiority of the plots which have received lime over those which have not, is well shown in the curves at the end of the articles and by the grouping of the plots in Table No. II, and, so far as can be judged from the results obtained during the past four years, it can safely be stated that *lime has a*

decided value in the preservation of fertility in acid soils under continuous green-cropping.

Within what we may term the 'Lime' group the decrease in yields falls into four quite distinct sub-groups. The first comprises (not unnaturally) the plots to which lime only was applied, and also the large Sulphate of potash plots, with decreases of 0·26 and 0·24 respectively. This is followed by the small Sulphate of potash group with a loss of 0·17. Both small and large applications of Nitrate of potash come next with only 0·14 and 0·06 decrease respectively while the remaining group, namely, that receiving lime and Sulphate of ammonia only, is the only one which does not show any loss for 1921, the yield being 0·28 tons per acre above that for 1920.

If these small differences may be regarded as having any definite meaning, they would appear to indicate that the beneficial effect of the potash manures, and particularly of the Nitrate of potash is still very considerable, while the action of the purely nitrogenous manure (ammonium sulphate) is still so strong as to counteract the loss of nitrogen from the soil, caused by continual pulling up of the crops, by over a quarter of a ton per acre.

We now come to the consideration of Table II, which, as in previous articles on this subject, shows the increase per cent. of the manured plots over the checks.

The order of the plots has been somewhat altered however in order that all those receiving manures of the same or a similar nature might be arranged together in groups and sub-groups.

LIME. (Average Inc. % 1503·5. Inc. over other plots 777·5%.)

Group.		Manuring.	Percentage increase over check plots. 1918	1919	1920	1921
NO LIME		Carbonate of Magnesia ... ... Sulphate of Ammonia	18	71	95	726
(A)		Lime only	—14	44	105	1100
(B)		Lime ... ... Sulphate of Ammonia	9	62	110	1466
(C) SUPERPHOSPHATE. Av. Inc. % 1429·5 Inc. over other plots 15·5%		(a) Lime ... ... Sulphate of Ammonia ... ... Superphosphate	49	81	153	1053
		(b) Lime ... ... Sulphate of Ammonia ... ... SUPERPHOSPHATE	41	224	267	1804
(D) POTASH. Av. Inc. % 1651 Inc. over other plots 421%	SULP. OF POTASH. Av. Inc. % 1729 Inc. over other plots 401%	(a) Lime ... ... Sulphate of Ammonia ... ... Sulphate of Potash	14	100	140	1353
		(b) Lime ... ... Sulphate of Ammonia ... ... SULPHATE OF POTASH ...	—83	121	266	2105
	NIT. OF POTASH. Av. Inc. % 1573·5 Inc. over other plots 215·5%	(c) Lime ... ... Nitrate of Potash	—5	57	109	1230
		(d) Lime ... ... NITRATE OF POTASH ...	—7	210	219	1917

In order to facilitate the reading of the individual "plot" curves as percentage values of the original unmanured soil, an additional scale is given on the right hand side of the chart on which the value 100 has been given to the yield from the check plots in 1918, the year of first application of the manures.

The most noticeable feature of both the Table and the Charts is the sudden very great rise in percentage increases this year throughout the series.

This is partly, but by no means entirely, accounted for by the fact that very poor crops were obtained on two of the three check plots, these having suffered disproportionately from the adverse weather conditions in May, owing to the decreased fertility of their soil. All the other plots, however, suffered to some extent, though probably in a lesser degree, from the same cause.

A further explanation must therefore be looked for as to why the 1921 crops from the majority of the plots show little or no decrease in spite of the poor season, and it is in the increased and possibly still increasing fertility of the manured plots, rather than in the decreased and decreasing fertility of the check plots, that it is probably to be found.

In this connection it will be especially noticed that the Magnesia and Superphosphate plots are the only ones which show a marked decrease from 1920—a favourable year for green crops. Further, the former are the only plots which do not show a decided increase over the yield for 1919, which was the only previous unfavourable season, and even this may be accounted for by the inclusion in the results for 1921 of the third "Magnesia" plot, which has been disregarded in working out the figures for previous years as being abnormal, owing to the presence on it of a large white-ant teelah, which had to be dug out when the experiment was started, thereby causing the removal of almost all the surface soil from this plot.

Apart from marked increases over the check plots shown by all manured plots in common, it is of interest to note that the potash salts have this year given decidedly larger increases in crop

than Phosphoric acid (as Superphosphate), Sulphate of potash being easily first, the Nitrate second, and Superphosphate third, both for the small and large applications.

Leaving the excessive doses of potash and Phosphoric acid out of consideration however, we again find Sulphate of ammonia at the head of list and Magnesium carbonate at the bottom of it as on Table No. I ; " Lime only " holding fourth place just above the small dose of Superphosphate.

These positions are largely what one would have expected to find, and in this connection a brief consideration of the action of the various manures applied will not be out of place.

The action of most chemical manures on an acid soil, such as the one with which we are dealing, is two-fold.

Such manures are, of course, usually applied mainly, if not entirely, for their food-value to the crop which it is desired to produce, but their action is by no means entirely, or even primarily, biological. On the contrary, the immediate result of applying most manures of this kind to an acid soil is a purely chemical one.

One of the most important results of this, and of the previous series of similar experiments at Borbhetta by Hope and Andrews (3), has been the very marked way in which the initial depressing effect of potash, as contrasted with the immediate stimulating effect of Phosphoric acid (as Superphosphate) has been brought out, both in the case of tea and of green crops.

Chemical analysis of the Borbhetta soil—which is typical of the acid Tea soils of this part of Assam—reveals the presence of certain salts of aluminium, which are either soluble in water themselves, or at least potentially capable of producing Alumina in soluble form, if acted on by the salts of strong acids, such as some of the chemicals with which we are dealing.

Carpenter and Harler (4) have shown that such "soluble Alumina is toxic," even when present only in such minute quantities as one part per million, and the same writers attribute the initial depressant effect of potash manures on tea and other crops directly to the power of this chemical of converting insoluble salts of

Aluminium into a soluble form, in which they immediately pass into the soil solution and exercise a toxic effect on the crop.

Superphosphate on the contrary, the action of which has been very thoroughly worked out by Meggit (5), has exactly the opposite effect on these soils, as also has Lime.

For, whereas potash manures tend to liberate soluble Alumina, lime or phosphatic manures tend to fix any that may already be present in the soil solution as insoluble Aluminium phosphates or oxide, or as Calcium aluminate, none of which salts have any toxic action on plants.

These facts are clearly borne out by the figures on our tables, which can thus be the more readily understood.

The initial depressant effect of the potash manures, so noticeable at first, has now worn off completely, normal soil conditions having become re-established as the percentage of potash in solution has gradually decreased until it has become too weak to liberate further toxins, with the result that the very considerable food value of these manures has been able to exert a steadily increasing beneficial effect on the crop, as compared with that of the check plots, during the last three years.

Phosphoric acid (as Superphosphate), on the other hand, was immediately available as plant food from the start, being subject to no such check from toxic alumina as that suffered by the potash plots, but rather the reverse, with the result that its food value is now declining, partly owing to exhaustion, but also possibly partly to the gradual reversion to the soluble (toxic) form of the Alumina which it rendered insoluble when first applied.

Summary.

Apart from a slight general decrease in crops due to the seasonal influence, this year's results may be compared with those obtained in the three previous years as follows :—

(1) *Lime alone* continues to produce a definite increase in fertility and has more than maintained its superiority with regard to the check plots.

(2) *Magnesia* (with Ammonium sulphate) on the contrary has fallen away considerably, both as compared with the combination of Lime and Ammonium sulphate or with Lime alone, though it has practically maintained its position with regard to the check.

(3) *The Potash Manures* in every case continue to show very big increases over the check plots, when considered in conjunction with Lime and Ammonium sulphate. In the case of the plots receiving Potassium sulphate, however, this is probably largely due to the additive effect of all three manures, for, if the beneficial effects of the Lime and Ammonium sulphate are eliminated from the calculation, it will be seen that the decrease in yield on these plots is only slightly less than that on the checks.

On the other hand the relatively very small decreases in actual crop shown by the Nitrate of potash are probably due entirely to seasonal influence, but for which there would apparently have been a decided increase in yield from these plots this year.

(4) *Phosphoric Acid* (as Superphospbate) has barely maintained its position in relation to the check-plots, even with the assistance of Lime and Ammonium sulphate. The crops on these plots, however, had suffered dis-proportionately from prematurity when gathered, although this cannot entirely account for the decreases shown by them.

CONCLUSIONS.

(1) Ten maunds of Lime still produces in the fourth year after application a strong residual effect.

It apparently tends at least to maintain if not to raise the fertility of all plots to which it was applied either alone or in conjunction with other manures.

(2) Magnesia now shows a rapidly diminishing effect, and

after the second year its value has always been definitely inferior to that of lime.

(3) Phosphoric Acid shows no further increase in fertility in the fourth year either for the large or small dressings of Superphosphate, but rather the reverse. The residual effect, however, is still sufficiently strong to maintain very large crop increases over the check-plots, and, in the case of the heavy dressing only, an increase of half a ton per acre over the 3 plots receiving no Superphosphate but the same other manures.

(4) Potash salts continue to show marked beneficial effect after a lapse of four years, this being especially so in the case of the Nitrate, which has this year produced greater increases in fertility than any other single manure with the exception of Ammonium sulphate.

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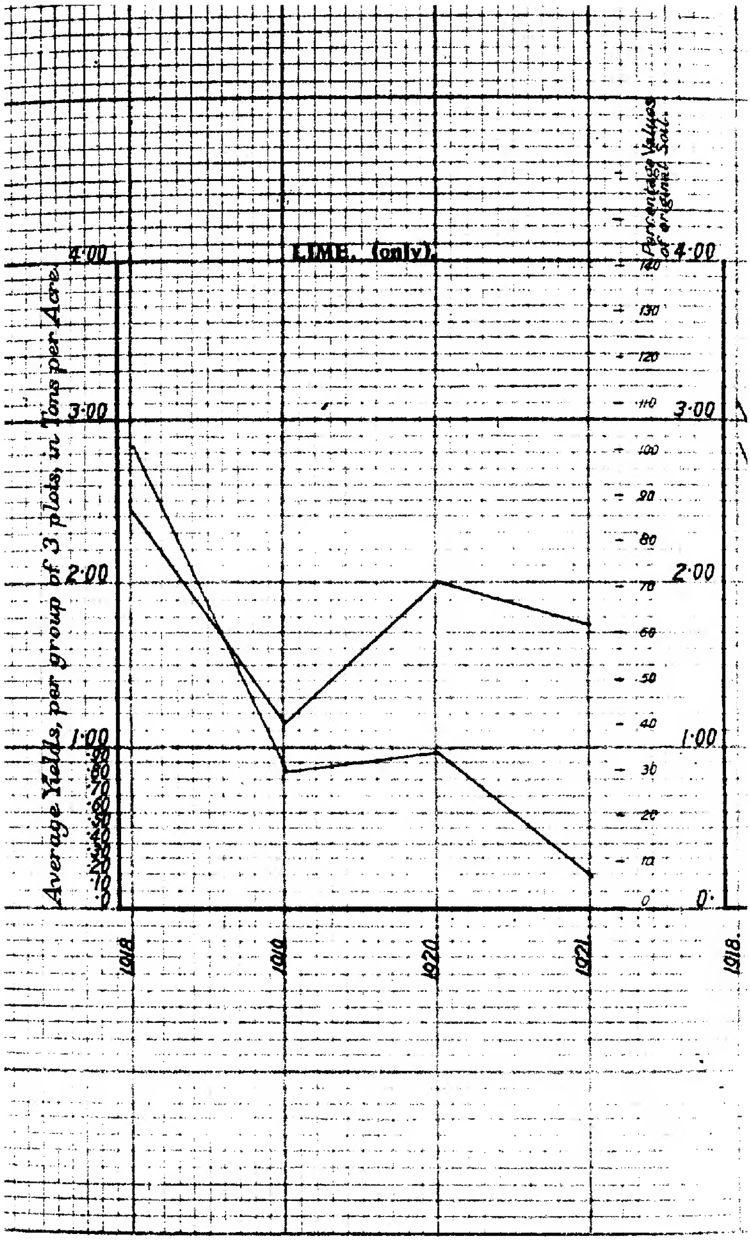

LIME. (only).
Average Yields, per group of 3 plots, in Tons per Acre.
Percentage Values of original Soil.
4·00
3·00
2·00
1·00
0·
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
1918
1919
1920
1921
1918.

NOTES.

The Preservation of Timber—The chief and effective preservation of timber from attack by fungi and insects is a problem which is constantly before the planter. Many processes have been recommended, most of which demand that the timber should be either kiln-dried or treated with preservatives in a vacuum. Neither of these two processes is possible on a tea garden. The recommendations put forward by the Forest Products Laboratory, U. S. A., which follow, may therefore be of some interest. Green timber which cannot be kiln-dried is liable to attack by fungi, many of which produce blue stains, and which in any case render the timber liable to rot. It has been found that the attacks of fungi may be prevented by dipping the wood into warm solutions of either sodium carbonate (soda ash) or sodium bicarbonate. In wet weather an 8 per cent solution of the carbonate, or an 11 per cent solution of the bicarbonate, can be used, and the concentration of the solution can be reduced to 4 and 5 per cent respectively in dry weather. The timber should be treated immediately after sawing and then piled in such a way as to ensure ample ventilation.

This recommendation seems delightfully simple, and would be inexpensive, and with the authority of the Forest Products Laboratory behind it would seem to be well worth a trial, more especially since soda ash is easily procurable and is now-a-days kept in stock on most up-to-date gardens.

E. A. A.

Temperature control of firing machines.—At the present time when the necessity for the production of the best tea possible is of paramount importance, all that can aid in this direction is of importance and any mechanical device that will help to the attainment of greater control of the operations in tea manufacture needs to receive careful attention, and perhaps one of the processes that

is difficult to continually control throughout the working period is the temperature of the firing machinery. The fluctuations in the temperature can be rapid and of considerable amount through uneven firing, and unless a constant watch can be kept upon the machine thermometer there is no means of ascertaining whether this operation has been properly carried out. The thermometer on many machines is in such a position that it is difficult to read. An instrument that affords a means of simply and efficiently controlling the firing operation is a recording thermometer, of which there are several different makes at the present time on the market. A type, however, that has given good results in this direction is one of the type made by the Brown Instrument Company, Philadelphia, and is now quoted at the price of 60 dollars.

Whilst such an instrument is of use in any tea factory it is more particularly so in those factories where an Assistant Manager cannot constantly be in the factory during the time of manufacture. The instrument gives a continuous record of the temperature of the firing machine during the period it is at work and any irregularity in firing can be ascertained as also the extent of the irregularity and the time at which such occurred. The more extended use of recording thermometers in tea firing machinery is to be advocated as a means of assisting towards more efficient working.

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THE FUNGUS DISEASES OF THE TEA LEAF

BY

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(Continued from 1921, Part IV, Page 213).

Blister Blight—*Exobasidium vexans*, Mass.

In the course of the investigations careful enquiries were carried out on every garden in the Darjeeling district and the following conclusions were made.

Jat of tea: It was found that all jats of tea were attacked similarly. The only distinction that can be made is that in certain cases the dark-leafed jats of tea appeared to be less susceptible. Not only were all jats susceptible but no individual bushes were found to be immune.

Class and condition of soil did not make any appreciable difference to susceptibility.

Climate was found to be the most important factor in the distribution of the disease. Elevation alone was only of importance in so far as it influenced the temperature and humidity. The optimum temperature is somewhere in the neighbourhood of 60°F and the damper the atmosphere the better for the blight As a rule the best conditions for the blight are when a few days of good growing weather are succeeded by dull cool weather. The good growing weather provides an ample supply of suitable leaf and the succeeding dull damp weather gives optimum conditions for the distribution of the spores of the blight. Shade, particularly damp shade, favours the disease and bright sunshine is the best cure known.

Cultural conditions are only important in so far as they regulate the condition of the leaf. The more succulent the leaf, the more liable it is to attack. Manures tending to produce rank growth, *e.g.*, those rich in nitrogen, tend to increase the susceptibility to attack. One of the most important factors governing the condition of the leaf is the pruning of the bush. The heavier the pruning the more succulent the leaf. Pruning is also important from the following point of view. Badly pruned and unpruned bushes have a lot of twiggy wood inside the frame and young shoots are often present on this wood in the cold weather. The blister frequently may be found on those shoots throughout the year. They therefore act as harbouring places for the disease. Plucking is naturally of great importance as the only leaf blister can attack, is the succulent leaf.

The Presence of Exobasidium in the Jungle.

In the course of the investigations on blister blight in Darjeeling a prolonged search was made for the disease on other plants in the jungle in the neighbourhood of the tea gardens. Only one plant was found with a disease resembling blister blight. This plant was *Symplocos theæfolia*, Kherani. A careful investigation of the fungus on it led to the conclusion that although it was an *Exobasidium* it was probably a different species from that found on tea. It was then concluded that the tea disease fungus was not present in the jungle. Later on, however, an outbreak of blister occurred in the Mangaldai district on a garden adjoining the hills. There seemed to be nothing to account for the sudden appearance of the disease as the garden in question was well isolated from other tea. The gardens in North Lakhimpur and a few in the Dooars were also affected similarly. A study of the climatic conditions of these gardens revealed nothing strikingly different from the other gardens in the districts in which they were situated. Their geographical situation was then studied and it was found that deep valleys cut off most of the gardens in the districts which are so far immune from direct communication with the higher ranges of the Himalayas while the gardens on which the blister had appeared were not so isolated. It seemed

EXOBASIDIUM ON SYMPLOCOS THEÆFOLIA (KHERANI).

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possible that the disease had some connection with the higher ranges of the Himalayas. All the gardens in Tezpur, Bishnath and Behali have never had blister, while those near the hills in Mangaldai and North Lakhimpur get it. In Darjeeling this opinion was strengthened by the knowledge that the disease started at the top of the Rungbong valley in 1909 and did not reach the Teesta valley gardens until two years later. The disease was found at Munsong on a few acres of tea planted in the cinchona in 1907 or 1908. In 1908 it was found on two gardens in the hills near the Dooars and another in Bhutan. Rungbong valley is in direct connection with the higher ranges while the Teesta valley is cut off from them by the valleys of the Teesta and Rungeet. An explanation of this apparent connection with the higher ranges of the Himalayas was then sought. From native rumour it was learned that the *Rhododendron* forests were attacked by a disease similar in appearance to blister blight. It was some time before an opportunity could be made to further investigate this, but in 1919 the Mycologist visited the *Rhododendron* forests in the neighbourhood of the Jelap La Pass. He timed his visit so that he would arrive there at the time when blister would be likely to appear. As the season was exceptionally dry he delayed his departure until he got news that *Exobasidium* was actually prevalent on some of the jungle trees. He then set out accompanied by two Lepcha botanical collectors from the Lloyd Botanic Garden for the Jelap La Pass into Tibet. He reached Kalimpong the first day *viâ* Rungeet valley and Melli bridge. He went on next day to Pedong where he stayed for some days while the jungle was searched for the blister. Here he had the pleasure of meeting Mr. Green of the Munsong Cinchona Plantation, who gave him a list of the trees on which he had observed disease resembling blister blight. The Lepchas had meanwhile obtained *Exobasidium* on Ungiri (*Pieris ovalifolia*) Kherani (*Symplocos theæfolia*) and another shrub which they also called Kherani. Successful cultures were made of these and microscopic slides, drawings and photographs prepared. A move was then made to Sedonchen, spending one night at Ari *en route*. At Sedonchen the Mycologist camped for some days while the

Lepchas searched the jungle round Gnatong (12,300 ft.) and the Jelap La Pass (14,300 ft). The road below Sedonchen climbs up a magnificent gorge, passing successively all classes of vegetation, from tropical to Alpine forests. It is very steep, rising over 10,000 ft. in 20 miles. The *Rhododendron* forest begins about 9,000 ft. above sea-level and continues to about 13,000 ft. It was in this belt that the *Exobasidium* was most prevalent. The weather was very wet and the mountains were enveloped in thick mist, just the thing for the blister blight and the epidemic of disease was just at the right stage when the Mycologist observed it. All species of *Rhododendron* seemed to be attacked and the yellowish or pinkish blisters were almost as noticeable a feature of the landscape as flowers. Cultures, slides, photographs and drawings were obtained of *Exobasidium* on five species. The natives stated that this disease had only appeared in recent times, *i. e.*, within their recollection; but this information may not be reliable. When no further specimens were forthcoming the Mycologist returned to Darjeeling *viâ* Pedong, Kalimpong and Rungli Rungliot. It was found that the shapes and sizes of the *Exobasidium* spores varied very considerably not only on the different species of *Rhododendron* but also on the same species. Some of the blisters examined had spores of size and shape similar to those found on tea. Unfortunately it was not possible to carry out inoculation experiments on tea as the cultures did not survive the journey to Assam and so far it has been impossible to spare the time to make another trip to collect fresh material. Special precautions such as the provision of cool incubators, ice boxes, etc., are necessary to ensure the satisfactory growth of this fungus on artificial media under the climatic conditions of Assam in the rainy season. The blister blight of tea very rarely survives the journey from Darjeeling to Assam. It is obvious that the disease was not introduced into Darjeeling in peoples' clothes or in any other accidental way of a similar nature from Assam. It is extremely unlikely that the disease was carried in tea seed as Assam tea seed from infected gardens has been exported to many places for many years without any outbreak of blister blight following. It seems much more probable, in view of the infor-

Exobasidium sp. on jungle trees growing in the *Rhododendron* forests of the Himalayas near the

mation given above, that the disease has spread from somewhere north of China through the *Rhododendron* forests of the Himalayas and that it reached Darjeeling in this manner. During a portion of his long leave the Mycologist paid a visit to one of the higher mountain ranges in the Naga Hills and found the disease in the *Rhododendrons* there also. The plate shows the appearance of *Exobasidium* on various species of *Rhododendron* and allied plants. Until further work has been carried out on these species of *Exobasidium* it is impossible to say which, if any, is identical with that found on tea. They all vary so much individually that it is possible they are all the same species.

These *Rhododendron* forests are a long way from the present tea gardens and it may well be asked how the fungus covers the intervening distance. A study of the temperature records in relation to outbreaks of the disease shows in many cases that a sudden fall in temperature occurred ten days to a fortnight before the disease appeared. In Darjeeling and other places close to the Himalayas a sudden fall in temperature is generally due to a wind from the mountains. In cases where there is no deep, hot valley in between the spores of the blight could easily be carried the required distance without injury. The intervention of a deep valley would alter the humidity and temperature of the wind besides possibly changing its course. As it takes ten days to a fortnight for the disease to develop blisters after infection it is possible that infection took place about the time the spores causing the outbreak were borne on the wind which caused the lowering in temperature.

Treatment.

Manuring: Some experiments were made with manurial applications and salt and potassium chloride were tried with a view to checking the growth of young leaf temporarily. They did check the growth and reduce the intensity of blight attack in consequence. It was hoped that this temporary check would enable the spraying or other treatment to get ahead of the blight. It was not altogether satisfactory as the climatic conditions are such that the effect both of the manure and the spraying only persisted a very short time.

Spraying : A great many experiments were made to determine the best spray fluid. It was found that spraying alone is only a palliative whatever solution is employed. The climatic condition and the manner in which tea grows make it impossible to cure a disease like blister blight by spraying alone. The spray fluids experimented with may be divided into three groups. Firstly, those calculated to stimulate the plant so that the leaf will grow more rapidly than the fungus ; secondly, those intended to check the growth of the leaf and cause the succulent leaves to harden rapidly thus making them less liable to attack, and thirdly, those whose action is fungicidal.

Spraying the bushes with weak solutions of nitrate of soda was tried with the first object, but it was found that although the growth was to some extent stimulated the bushes were rendered more liable to attacks of such diseases as brown and copper blight. This method of treatement was therefore abandoned.

Salt and potassiam chloride solutions were tried for the purpose of hardening the leaves rapidly. They succeeded in their object but reduced the crop considerably. Their use, except in special cases, is not therefore recommended. The most satisfactory fluids were those which had a direct fungicidal action. Very many experiments were carried out with these. Bordeaux mixture in various forms and concentrations, Burgundy mixture and lime sulphur solutions were tried. It was found that for practical work solutions requiring special care in their preparation and application were undesirable. Burgundy mixture is easier to prepare than Bordeaux mixture, and although Bordeaux mixture of similar concentration is a better fungicide than Burgundy mixture the latter is preferable for practical use. Unfortunately both Bordeaux and Burgundy mixtures form precipitates and in their application it is necessary to keep them well stirred. This is seldom done properly on tea gardens and for this reason we have been led to recommend lime sulphur solution as the best all round spray fluid for practical use. The preparation and storage of the concentrated solution requires a little care, but it can be done at the tea house under European supervision, but there is little possibility of mistakes occurring in the field where supervision is necessarily more difficult.

Pruning and Plucking: On gardens where the tea is thoroughly well pruned and where there is no abandoned tea on which the disease may pass unobserved it has frequently been found possible to eradicate the disease altogether from the garden by the careful removal of all blisters in the cold weather. This of course is quite out of the question in the case of Darjeeling gardens as the distances between gardens are not great enough to prevent re-infection from neigbours, but careful pruning will in any case facilitate treatment of the disease. It is of course necessary to prune heavily at times, but whenever heavy pruning is carried out it should be done as early in the cold weather as possible so that good growth will be obtained before the blister blight season arrives. If this precaution is neglected it is probable that the young shoot will be killed right down to the heavy wood and some of the bushes may die right out. In any case it is desirable that heavy pruned tea be protected by frequent applications of spray fluid until satisfactory growth has been assured. None of the systems of plucking ordinarily carried out were found to influence the blight noticeably. Various planters in Darjeeling tried hard plucking with the idea that by removing all the succulent leaf the blister would die out for lack of food. This idea was very sound in theory but was impossible in practice as labour was insufficient to carry it out over the whole area. In consequence the heavy plucked blocks were re-infected from the surrounding tea and their last condition was worse than before. Under certain circumstances the removal of all succulent leaf is a very satisfactory method of dealing with the disease. For instance in the cold weather the careful removal of all succulent leaf from unpruned and light pruned tea and the spraying of the rest with fungicidal solutions does eradicate the disease and in the case of isolated gardens this method has been proved effective repeatedly.

The development of the disease in the leaf takes some time and when the leaf grows more quickly than the disease it is possible to save a lot of tea by plucking it before the disease has had time to produce blisters. Unfortunately under Darjeeling conditions the blister generally grows more quickly than the leaf and in

consequence the leaf is badly injured before it is ready for plucking. In Assam the rapid growth of the leaf prevents the disease doing much damage except on young and cut-back tea. In the growing season, however, the removal of all succulent leaf is not only impossible but undesirable when the attack is general. If there is no possibility of preventing further infection the removal of all succulent leaf would possibly cause more serious injury to the bush than the disease as the new leaf may be infected as soon as it appears and the bush may suffer by the abnormal restrictions of its leaf surface. If the leaves usually left in the bush are not removed although they may have blisters on them the uninjured portions will still continue their functions and the later flushes will lose little in vigour. On the other hand in the case of a small outbreak of the disease it is possible to prevent further spread and ultimately to eradicate the disease by close plucking the area in which it has appeared, taking precautions to prevent it from spreading to other areas by various methods to be discussed later.

Co-operative treatment: In the case of isolated gardens blister blight is not a difficult disease to eradicate, but in a district like Darjeeling where the gardens are so situated that isolation is out of the question the problem is very difficult. It is extremely unlikely that disease will ever be eradicated and it is quite impossible to even check a severe attack unless gardens act in strict co-operation. In 1913 one of the writers proposed a co-operative scheme for dealing with this disease and the scheme was favourably received by the planters. It was decided that it be tried on a small scale in a more less isolated portion of the district. The outbreak of war and the subsequent slump prevented the attempt being made. The scheme is described at length in *Quarterly Journal*, 1916, Part IV, pp. 142–153.

Summary of Recommendations.

The treatment of blister blight may be summarised as follows :—

1. The careful removal of all blistered leaves in the cold weather.

2. Keeping a careful watch for all outbreaks throughout the season.

3. Immediate isolation of infected areas. Only special coolies should be allowed to go into them and these coolies should change their clothes immediately afterwards.

4. The immediate removal of all blistered leaves and also the removal of all leaves liable to attack from the infected bushes and their neighbours. The leaves should be buried on the spot.

5. Spraying the infected areas with a fungicidal solution such as Lime sulphur solution, Bordeaux or Burgundy mixtures, immediately after removing the leaves.

6. Repeating the spraying of infected areas when the new leaves are appearing.

7. Heavy pruning should be carried out as early as possible.

8. All heavy pruned or young tea should be protected by repeated applications of spray fluid.

FACTORS AFFECTING THE QUALITY OF TEA

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The Notes on Tea Manufacture published in *Quarterly Journal* 1921, Part II, were received with so unexpectedly great an interest, and led to so many questions dealing with the subject of quality generally and particularly on the purely scientific side, that it is thought well to add more detailed information to the admittedly scrappy notes given in partial explanation of the practical manufacturing operations advised.

Part I.

Constituents of the Tea Leaf: In tea leaf the following are the more important substances found:—caffeine, essential oil, albuminoid substances, the ash constituents (lime, potash, phosphoric acid, silica, etc.), gummy substances and tannin.

As before stated, *caffeine* although responsible for the refreshing properties of tea is a colourless, odourless and practically tasteless substance and would not therefore be expected to influence the market value of tea.

The *essential oil* is prepared by distilling tea with steam, and dissolving the oil with ether from the water with which it distils over. The essential oil is thus obtained in very small quantity. Bamber found about 3 parts in 10,000 parts tea, and describes it as forming colourless, highly refracting, irregular-shaped drops. Von Romburgh found only 6 parts in 100,000. The quantity obtainable being so small the essential oil has been very little investigated, It has been shown to contain acetone, methyl alcohol, and methyl salicylate which are factors in producing the aroma, but the substance responsible for the characteristic odour of tea has not been discovered. Green leaf possesses none even when crushed,

(although it contains some volatile oil), but properly withered leaf always has a pleasant smell resembling that of made tea, while the full aroma only appears during firing. The percentage of volatile oil increases after fermentation, and decreases during firing by evaporation.

The *albuminoids*, being extractable by boiling water only in small quantity, are of little interest. They do, however, probably render some of the tannin insoluble during the fermentation process and therefore have an indirect influence on quality.

In Japan it has been found that amino-acids have an influence on the quality of green tea. The quantity of these compounds in the leaf is increased by manuring with nitrogenous manures and flavour is also increased. With black teas in India nitrogenous manuring tends rather to decrease than to increase quality probably by lowering the tannin content (marked pungency is not esteemed in green tea) and it may therefore be assumed that these amino-acids have little influence on the flavour of black teas.

The *ash constituents* can have little or no direct influence on quality, but Mann gives a few analyses showing that teas of good quality contain higher proportions of phosphoric acid and potash than poor teas.

Gummy substances (pectin, pectoses, etc.) occur in considerable quantity, and dissolve to a great extent in boiling water. Bamber suggests that they may affect quality by increasing the "thickness" of the liquor. On cooling they form substances of a gelatinous consistency, which Bamber suggested might form part of the solid which is precipitated out of solution when good teas "cream down." "Creaming down," however, is probably due to certain properties of tannin and caffeine which will be mentioned later.

Tannin has a marked astringent taste and is present in considerable quantity in the infusion made with boiling water. It therefore greatly influences the taste of the liquor. Its fermentation products are strongly coloured and therefore influence the colour of the liquors. At least one of the fermentation products has an agreeable sweet taste.

It would appear, then, that the quantity of tannin present should be an appreciable factor in influencing quality as measured by market price.

Influence of Tannin on quality :—Hooper and Mann have separately published a certain number of analyses showing some connection between tannin content and market price.

Mann quotes the following figures :—

	Cachar Pekoe.	Duars Pekoe.	Duars Pekoe Souchong.	Assam Pekoe.	Assam Orange Pekoe.
Value in annas ...	4/2	4/2	3/8	5/2	7/6
Total matter dissolved ..	28·38	26·29	23·69	29·38	31·58
Tannin %	7·56	7·29	6·48	8·23	10·98

These figures were obtained after five minutes' extraction at the boiling point of water.

In 1914 and 1915 a large number of analyses were made by the writers, but were not published partly because the results were not very definite, and partly because the chemist chiefly concerned left the Department for war service before the work was completed.

If only to save further effort in the same direction the results are now summarised as shortly as possible.

In addition to total tannin* and caffeine, the total soluble solids, and "combined" tannin and caffeine, were estimated.

A strong infusion of tea deposits on cooling a dark-coloured precipitate ; the tea is said to "cream down." A worker

* Tannin was estimated by titration with permanganate of the extract (to which indigo carmine had been added), before and after precipitation of the tannin by gelatine. The factor used for calculation was 1 cc. N. K Mn O_4 = ·0416 grams tannin. The method therefore estimates all the soluble oxidisable matter which precipitates gelatine, and includes all substances which possess tanning properties. Total solids were determined by evaporating a part of the extract to dryness. In all cases results are calculated as percentages of the dry tea.

(unnamed) in the "Lancet" laboratory showed that this precipitate contained caffeine and tannin, roughly in proportion (by weight) of 3 parts tannin to 1 part caffeine. He suggested that a compound of tannin with caffeine had properties different from that of a mere mixture of tannin with caffeine, that the supposed harmful physiological effects of free tannin and free caffeine were reduced by the combination of the two to form a compound, and that this compound possessed an agreeable flavour superior to the coarse pungency of free tannin. The "Lancet" worker published a number of analyses of good and bad teas showing that the ratio of tannin to caffeine in good teas was roughly 3 : 1, while in teas of poorer quality there was an excess of one or the other.

The rough proportion of 3 parts tannin to 1 part caffeine in the "creaming down" precipitate was confirmed in the Tocklai laboratory. This "cream" was found to be more completely precipitated when salted out by saturating tea extracts with ammonium sulphate, and a precipitate of similar composition was obtained even from weak tea infusions by saturating the liquid with ammonium sulphate. In the following analyses "combined caffeine" was estimated by saturating the infusion with ammonium sulphate, and estimating the caffeine in the precipitate. The figures given under "combined tannin" are approximations obtained by multiplying the percentage of "combined caffeine" by 3.

Extracts made by the methods used by tea tasters, were found to vary very considerably in composition and to such an extent that they could not be used for supplying analytical data. The extracts analysed were prepared by boiling 5 grams of tea with 400 cubic centimetres of water for half an hour under a reflux condenser, cooling, and making up the volume to 500 ccs. By this method extracts of constant composition were obtained.

The following table (Table I) shows the results obtained on samples of B. O. P. The prices given are with few exceptions Calcutta valuations (1914) at about the same time. In a few instances selling price only could be obtained.

TABLE

Broken Orange

Day Book No.	Number of samples in order of value.	Valuation.			Total tannin.	Total solids.	Percentage tannin in total soilds.	Total caffeine.	Combined caffeine.	Combined tannin.
		Rs	As.	P.						
39	1	3	0	0	27·3	47·3	57·7	7·36	3·49	10·5
57	2	0	13	6	20·1	42·8	47·0	4·65	3·77	11 3
60	3	0	12	6	18·1	44·0	41·1	.....	...	.....
44	4	0	12	6	16·1	43 6	37·4	4·87	2·77	8·3
71	5	0	12	0	18·5	43·9	42·1	6·63	2·06	6·2
12	6	0	11	6	15·4	42·7	36·1	4 8	2·0	6·0
36	7	0	11	0	21·2	42·7	49·9	5·04	4·05	12·2
27	8	0	10	9	16 3	43·6	37·4	4·52	3·14	9 4
59	9	0	10	6	19·4	43·7	44·4	.....	.....	.....
29	10	0	10	3	19 3	43·1	44·8	.....	.....	.....
74	11	0	10	0	17·5	43·9	40·0	4 31	3·02	9·1
6	12	0	10	0	13·7	41·3	33·2	4·44	1·73	5·2
31	13	0	9	9	17·5	42·4	41·2	4 07	3·32	10·0
25	14	0	9	6	18·3	43·6	42·0	4·96	3·36	10·1
35	15	0	9	4½	18·2	44·9	40·5	4·23	2·95	8·9
46	16	0	9	3	16 1	43·0	37·7	3·62	3·31	9·9
77	17	0	9	0	14·9	43·9	33·9	4·44	4·05	12 1
18	18	0	9	0	18·8	41·6	45·2	4·54	2·70	8·1
20	19	0	8	9	18·5	43·2	42·8	.....	.....	.....
21	20	0	8	9	17·5	42·2	41·5	4·53	2·55	7 6
55	21	0	8	7½	18·5	43·2	42 8	5·72	3·10	9·2
16	22	0	8	4½	18·5	41·3	44·8	4·40	2·34	7·0
75	23	0	8	3	13·5	41·6	32·5	3·48	2·80	8·4
7	24	0	8	3	14·4	40·6	35·5	4·18	2·63	7·9
24	25	0	8	3	18·0	42·7	42·1	5·60	2·57	7 7
40	26	0	7	10½	15·9	40·2	39·5	4·68	.....	.....
13	27	0	7	10½	18 5	41·3	44·8	3·09	2·70	8·1
32	28	0	7	9	14·0	41·1	34·1	3·71	2·80	8·4
69	29	0	7	7	13·7	40·4	33·9	4·93	3·90	11·7

I.

Pekoes.

Solids not caffeine or tannin by difference.	Free tannin.	Free caffeine.	Remarks and Tasters' Report.
12·6	16·8	3·87	Fine pungent liquor. Cup colour good. Infusions bright. Dry leaf good make and very good bright tip.
18·0	8·8	0·88	....
.....	.....	.....	....
22·0	7·8	2·10	Fair liquor lacking in briskness. cup colour fairly good. Infusions bright. Dry leaf good make and twist some bright tip.
19·8	12·3	4·57	....
22·5	9·0	2·8	Fairly good infused leaf. Fair quality. Brisk, fairly strong and coloury, little point. Well made leaf. Even fair tip.
16·5	9·0	1·0	....
22 8	8·9	1·4	Liquors too thin but fair strength. A little flavour but wanting in quality. Infusions dull and green. Dry leaf well made. Fair amount bright tip.
.....	.....	.....	B. O. P. Liquor a little strong and full. Infusions fair.
.....	.....	.....	....
22·1	8·4	1·29	Useful B. O. P. with fair tip.
23·2	8·5	2·71	Good size, little mixed with fannings few tips, wanting in briskness fair colour and strength liquors barely equal to usual standard.
20·8	7·5	0·75	....
20 3	8·2	1·60	Liquors fair colour and strength. Infusions fairly bright. Dry leaf useful make.
22·5	9·3	1·3	Blackish leaf, colour fair, Brisk liquor. Infused leaf a shade dark.
23·3	6·2	0·31	....
24·6	2·8	0·39	....
18·3	10 7	1·84	Nice liquors with a little flavour. Useful colour strength. Infusions fairly bright. Dry leaf useful.
.....	.....	.....	Leaf black broken pekoe fair tip clean brisk liquor.
20·2	9·9	1·98	Plain liquor. Useful colour and strength. Infusions not very bright. Dry leaf has fair size and make.
19·0	9·2	2·62	Clean plain liquor. Cup colour fairly good. Infusions a little bright. Dry leaf good make.
18·4	11·5	2·06	Liquor fair colour and strength. Infusions fairly bright. some green showing up. Dry leaf a little mixed.
24·6	5·1	0·68	....
22·0	6·5	1·55	....
19·1	10·3	3·1	Clean but rather light liquor. Cup colour fairly good. Infusions show up a little green. Dry leaf has good make.
19·6	.....	.....	....
19 7	10·4	1·39	Liquors fairly bright with useful colour and strength. Infusions rather dull mixed. Dry leaf useful size and make, B. O. P. very flat and Flakey.
23·4	5·6	0 9	....
21·8	2·0	1·03	....

In the case of the No. 5 tea selling price on the London market only was obtained, and for comparison with the others its value has been put down as 2 annas less than the number of pence per lb. paid in London.

Tasters' reports are given in cases where they were obtainable.

It will be seen that the percentage of combined caffeine present has no apparent relation to the market price, neither has the percentage of free tannin.

The total caffeine, although the extreme variation is between 3·09% (near the bottom of the table) and 7·36% (at the top of the table), is in only a few instances greatly different from between 4 and $4\frac{1}{2}$ per cent., and such variation as exists is quite irregular. Total caffeine, then, cannot be correlated with price.

The total solids vary only between 40·2 and 47·3, and the percentage is rarely far from 43, yet high figures are fairly consistently found at the top of the table, and low figures at the bottom.

The figures for total tannin vary between 13·7% and 27·3% and the correlation with price is not to close as in the case of the total solids, yet here too, high figures appear at the top of the list, and low figures at the bottom. Tannin is assumed to give liquors the quality known as "briskness" and "pungency." Since this is not the only factor affecting the value, this one factor cannot be expected to show a very strict correspondence with price.

Mere appearance, including the colour of the dry tea and presence of tip, has a great value. Neither are the fermentation products of tannin, which affect the colour and taste of the liquors, estimated by the method adopted.

Averaging over ranges of price the following figures are obtained:—

BROKEN ORANGE PEKOE.

Valuation.	Total tannin.	Total solids.
11 annas and above ...	18·1	43·8
10 " " " ...	17·7	43·1
9 " " " ...	17·3	43·2
8 " " " ...	17·0	42·2
7 " " " ...	15·3	40·7

While the highest and lowest priced stand out as comparatively high and low respectively in tannin, there is little average variation between 8 and 10 annas.

In total solids again the highest and lowest show up, and there is a remarkable regularity in teas valued between 9 and 11 annas.

It may be said therefore that comparisons of total tannin and total solids will at least distinguish between very good teas and very bad ones although teas of approximately the same class cannot be placed among themselves.

On teas other than B. O. P. the following averages were obtained after analysis of 40 samples, mainly Pekoe-Souchong :—

Valuation.	Total tannin.	Total solids.
9 annas and above ...	15·7	41·1
8 " " " ...	14·8	40·6
7 " " " ...	13·8	39·7
6·6 " " " ...	14·2	39·6

The low average figures compared to those from B. O. P. are noticeable. This however is frequently accounted for by the fact that many of them were not broken teas, while even the broken teas are much coarser than the B. O. P.'s

Being less finely divided, these teas will not give up so much of their soluble matter to boiling water, and therefore give liquors of less "strength," which, in general, seems to be the quality measured by estimation of total solids and tannin. That liquors must possess quality other than strength so measured, is shown by the fact that for example B. O. P.'s averaging 15·3% tannin and 40·7% total solids are valued at only 7 annas, while less broken teas averaging 14·8% tannin and 40·6% total solids are valued at 8 annas. This was in 1914: whether the less strong liquors would be valued so highly on the present market, is doubtful. Our assumption, then, is that the total soluble solids and tannin give a rough measure of "strength," while the total tannin alone gives a still rougher measure of "briskness" or "pungency."

It is interesting to see how far these assumptions are borne out by the tasters' reports shown in table I.

The No. 1 tea with the exceptionally high tannin content is noticed for its "fine pungent liquor." "Strength" is not noticed. The total solids are only high on account of the tannin present. The solids other than tannin are lower than the average of this class of tea. The No. 4 sample is noticed as "lacking in briskness," and its tannin content is noticeably low for teas of that value. Both Nos. 6 and 12 samples (from the same garden) are comparatively low in tannin. No. 6 is noted as "brisk," which is not in accordance with expectation. This invoice, however, is notably higher in tannin than the other invoice which is noted as "wanting in briskness." The briskness of the No. 6 is possibly only comparative, since all the teas analysed from this garden are below the average in tannin and total solids and presumably get their price for qualities other than strength. They frequently show flavour above the average of the teas analysed, from which teas from districts giving much flavour were excluded in order to avoid interference from the flavour factor as far as possible.

The No. 7 sample possesses high tannin, and although briskness is not alluded to, "strength" is. The green infusions infer improper fermentation, high tannin being retained at the expense of the necessary fermentation products of tannin.

The No. 9 sample shows high tannin and total solids and is noted as strong and full. Briskness is not mentioned.

No. 14 also analyses well in tannin and total solids. The liquors are only referred to as being of fair colour and strength.

No. 15 is noticed for its brisk liquor and contains tannin above the average for its price.

No. 18 of high tannin content is only noticed for useful strength but No. 19 of about the same tannin content is noted as "brisk."

The high tannin of No. 21 again escapes notice, while that of No. 22 is noted as "strength."

No. 25 only retains a high tannin content because not well fermented. The liquors are light ; and the infusions green because insufficient tannin has been changed to colouring substances during manufacture.

No. 27 is notably high for its price both in tannin and total solids. The taster notices its strength. The low valuation is apparently on account of lack of other qualities. The dull and mixed infusions would lead one to believe that the manufacture had gone wrong in directions that will be briefly alluded to later.

On the whole our assumption as to the effect of total tannin and total solids seems justified, although there are obviously other factors determining quality as measured by market value.

The substances produced by the fermentation of tannin are not estimated by the method used for the determination of "total tannin."

The nature of these substances and their probable influence on quality is indicated by the following brief account of the chemistry of tea tannin. The most complete account yet published is that of Deuss,* from which most of the facts given below are taken. Deuss prepared pure tannin both from made tea, and, more easily, from green leaf. He found it a white powder, which does not crystallize. When dissolved in water, the solution turns brown and on standing in air, becomes cloudy. This brown precipitate is presumably produced by oxidation of the tannin by oxygen from the air. This presumption is confirmed by the fact that when the cloudy brown liquid is shaken with dilute acetic acid and zinc powder (which has the power of absorbing oxygen), the brown colour disappears and a clear uncoloured solution is obtained.

From this solution pure tannin may be obtained by shaking with ethyl acetate which dissolves the tannin out of the water. This brown compound obtained by the oxidation of tannin is called "tannin brown," and is undoubtedly the substance mainly responsible for the brown colour of tea infusions.

* Medeelingen van the Proefstation voor Thee No. XXVII.

When tea tannin is boiled with dilute sulphuric acid for 6 hours, the solution becomes cloudy, and a red substance separates out.

This red substance is called "tannin red."

Similar formation of "reds" is a property of a certain class of tannins, among which are the oak-tannins, but not of all tannins. The formation of "reds" therefore places tea-tannin among this class.

"Tannin red" cannot be changed back to colourless tannin by zinc powder, and is therefore concluded not to be formed by simple addition of oxygen to tannin, but the change involves the splitting off of water from the tannin molecule.

"Tannin red" is present in quantity in infusion from made tea but is not present in infusion from fresh leaf. It is therefore produced during manufacture.

It has a sweetish flavour resembling cinnamon, and its presence therefore influences the flavour of tea. It is soluble in solutions containing tannin, and its presence accounts for the coppery tinge in infusions of black tea, for the colour of infused leaf, and of fermented leaf before firing.

It is much more soluble in hot solutions than in cold. The "creaming down" of a tea infusion is considered by Deuse to be largely the separating out of tannin red as the tea cools. The "cream," however, has been shown also to contain tannin and caffeine as before mentioned. "Creaming down" is therefore a more complicated phenomenon than a mere separation of "tannin red," although this may be concerned.

This tannin red is a most important constituent of fermented teas. A "copper colour," the "colour of a new penny," is always aimed at as the ideal in fermented leaf and infused leaf from made tea, and it appears highly probable that this tannin red, which appears only after fermentation, may be responsible for it.

The "tannin brown" apparently is the cause of the appearance of the "colour of an old penny" in over-fermented or otherwise wrongly fermented tea.

In the days of hand rolling, the rolled leaf was left in fairly tightly rolled balls to ferment, and planters who can remember those days are of opinion that this treatment produced a much better copper-colour than the present method of thin spreading of loose leaf.

The leaf was left in balls in order to fix the "twist" which in those days had a great influence on the price obtained. On hot, dry days it was noticed (see Tea Encyclopædia) that the outside of the ball became dark and discoloured, although the inside retained the desired colour.

The change to loose spreading apparently came in as "good twist" became less esteemed, and greater evenness of colouration was desired.

In the interior of the ball, the oxygen supply must be very limited, yet the desired colour was obtained.

It appears possible that what is desired in fermented teas is as much as possible of "tannin red," with only a minimum of "tannin brown."

This may possibly be obtained by limiting the supply of air during fermentation, but it is essential also that the fermenting leaf shall not become unduly dry. Mann's recommendation to hang wet cloths in the fermenting room receives a new explanation, both in preventing evaporation and in preventing draughts, or streams of air carrying fresh oxygen.

Greenness of the fermented leaf, and of the infused leaf, is caused by failure of the above indicated reactions to go on; either simply because fermentation has not been allowed to proceed far enough, or when the greenness is patchy, because that part of the leaf has escaped the rolling, so that the cells are not so reduced in vitality as to permit the necessary reactions to proceed. Patchy greenness may in some cases also be ascribed to uneven withering, whereby parts of some leaves escape the loss of vitality due to drying.

The action of enzymes undoubtedly present in fermenting leaf has not been dealt with in this article. The subject is under

investigation at Tocklai, and, no doubt in other places, but it is not desirable to publish anything yet.

It may be noted that the reactions going on in fermenting tea will go on in the laboratory without the intervention of any enzyme. The function of the enzyme in manufacture is probably that of a catalyst. A catalyst is a substance which will by its presence increase the rate of a reaction, although itself undergoing no change.

PART II.

It has been shown that there is only a very rough correspondence between quantity of tannin present in made tea and the price.

The evidence, however, points to the fact that it is largely because the method used estimates unfermented tannin only, and not the substances produced from it during manufacture. The tannin present in fresh leaf, however, being the source of its fermentation products, should have a more direct influence on the quality of the tea.

This point is very difficult to prove directly. It is difficult to obtain samples of unchanged green leaf from any distance; and it is still more difficult to obtain representative samples of green leaf and of the average tea made from it. The work could only be carried out satisfactorily by seeing gunnies of leaf of different tannin content through manufacture at the same time; taking proper samples of green leaf and of finished tea. Without a factory on the Experimental Station it would be very difficult to arrange for such work.

For the present it is assumed that the quantity of tannin present in the fresh leaf does directly influence quality, although, as will be shown, it is not the only factor, and its influence can be masked by differences in manufacture.

Certain work on the variation of tannin in the leaf has been done. During 1921 the variation in the tannin content of the leaf plucked was followed in the Tocklai Laboratory through the whole season.

The two "leaves and a bud" plucked were taken to the laboratory and there sampled. The sample was separated by hand into four parts : (1) the buds, (2) the first leaves, (3) the second leaves, (4) the stalk, and the tannin estimated in each part.

The "high pruned" tea was pruned to 14″ from the ground, leaving 4″ one-year wood. The "low pruned" tea which the previous year was unpruned (skiffed) was pruned to 10″ from the ground, leaving 4″ of two-year wood.

The average percentages of tannin in the dried leaf are tabulated below :—

		Singlo Light leaf.	Burma Dark leaf.
Bud ...	from low pruned	24·8	23·6
	from high pruned	25·9	25·2
1st leaf ...	from low pruned	26·0	24·9
	from high pruned	26·5	25·8
2nd leaf ...	from low pruned	20·5	20·2
	from high pruned	22·3	25·7
Stalk ...	from low pruned	11·0	10·6
	from high pruned	11·8	11·3

Influence of Jat : It will be noticed that the light leaf consistently gives a higher average tannin content than the dark leaf although the differences are small.

When trials have been made in separately manufacturing leaf from light and dark varieties respectively, the tea from dark leafed bushes has obtained slightly lower valuations than tea from light leafed bushes.

Influence of Plucking : The variation in tannin in the various parts of the flush are also interesting.

The bud contains slightly less tannin than the first leaf, hence possibly a slight loss of quality in plucking immature leaf.

The first leaf, however, contains very distinctly more tannin that the second leaf. The tannin percentage falls off continuously as more leaves are taken, hence the falling off in quality with coarser plucking. The small percentage of tannin in the stalk is very noticeable. This is the very young green soft stalk plucked with the bud and first two leaves. Old woody stalk would certainly contain still less tannin. Stalk, therefore, is rightly considered as lowering quality, although the reduction in price obtained for tea in which red stalk shows up, is out of all proportion to the lowering in quality of liquors due to the presence of the stalk.

Fine plucking, therefore, produces better average prices since the coarser 3rd and 4th leaves are excluded. As Mann points out, however, the quality of the first and second leaves is not improved by not plucking more leaves. The better average price from fine plucking is only due to making less of the coarser grades, with a corresponding decrease in crop.

With the same *fineness* of plucking, however, differences in the *closeness* of the plucking do make a difference to quality.

For example with bushes pruned to the same height, better quality is obtained on plucking two leaves and a bud after giving a short growth only, than on plucking two leaves and a bud from a longer shoot.

Mann gives as an example the following extreme case, from two plots treated similarly up till September (1905). The first was plucked after an interval of ten days, the second was plucked after an interval of twenty days, two leaves and a bud being taken in each case.

The ten day growth made tea giving ... 43·1% total solids.

Twenty ,, ,, ,, ,, ,, ... 40·2% ,,

Such a difference would undoubtedly have produced a very great difference in selling price. General experience is agreed that within certain limits the closer the plucking the better is the quality of the tea produced; but if plucking is too close quality again suffers from the immaturity of the leaf. Mann points out that the ideal would be to pluck every day, taking ready leaf only.

That, of course, is quite impracticable. In practice probably weekly plucking does best, both for quality and yield; ready leaf, only, being taken. The closeness of the plucking has to be regulated by the state of the bushes. So long as the bush remains vigorous the closer plucking gives both better quality and better yield; but the bush soon suffers if the plucking is over-close. In this matter the Manager, guided by local and his own experience, has to exercise judgment.

Influence of Pruning: That a difference is produced by pruning is also clearly indicated. It is a matter of general experience that forced rapid growth from cut-back tea produces worse quality than that from ordinary top-pruned.

Any operation which appreciably reduces the leaf area stimulates the bush to more rapid growth. The bush takes food from the soil in solution. The crude food materials in solution are taken to the leaf where they are manufactured into substances which the plant can use, and the excess of water is given off by transpiration. There must always be a tendency to balance between the amount of water taken in by the roots and amount transpired by the leaves. When the balance is seriously disturbed, as by pruning, so that the remaining leaf area is insufficient for transpiration of the water taken in by the roots, then there is a period of rapid growth to make up the deficiency. Such stimulation of leaf growth is one of the objects of pruning. By heavy pruning a forced rush of growth is produced, and such growth is "watery" and gives poor teas.

Very heavy cleaning out will produce a similar effect, but in this case the balancing leaf area is soon made up, and loss of quality is noticed for a short time only.

After heavy pruning also the plucking is taken from the end of a long shoot instead of a short one, or in other words the shoot is plucked further from its point of origin.

In the case of the Tocklai plots in 1921 "the low pruned" was giving its new shoots from two-year wood left practically leafless, and the "high pruned" from one-year wood carrying

some leaves. Both were plucked at 27″ from the ground, so that the "low pruned" shoots were plucked 17″ from their point of origin, and the high pruned shoots at only 13″ from their point of origin.

In this case the variation due to either factor alone would not be expected to be very great. Even the combined effect of the two factors is small as may be seen from the table, but it is distinct enough to show up in every single instance. The average of all parts of the flush from dark and light leaf tea together being :—

Low pruned	...	... 20·3% tannin.
High „	...	... 21·3% „

The difference in tannin content is probably sufficiently great to make an appreciable difference in the average price of the tea obtained from bushes of the two types of pruning. Previous to 1920, the plots had been treated identically.

Influence of Light : Hope showed that there is a direct connection between the amount of light falling on the leaf and the quality of the extract prepared from it. In this case the extracts were made under conditions approximating to the preparation of tea for drinking purposes. Several bushes were shaded by thatch such that half received natural sunshine, and the other half remained in heavy shade and never received direct sunlight. After a few days the shaded leaves became darker green, more shining, and the stalks were noticeably drawn out.

Analyses of the extracts gave :—

	Total solids.	Tannin.
1. In exposure	10·5	2·81
In shade	11·0	2·76
2. In exposure	8·0	1·96
In shade	9·0	1·70
3. In exposure	9·4	2·44
In shade	10·0	2·14
4. In exposure	10·8	2·36
In shade	11·0	2·11

While the total soluble matter is increased by the shading, the tannin is noticeably reduced.

Similar differences were obtained when bushes of the same type away from, and under Sau trees, were compared :—

	Total solids.	Tannin.
1. Away from Sau trees ...	10·1	1·75
Under Sau trees ...	11·1	1·44
2. Away from Sau trees ...	10·2	1·39
Under Sau trees ...	10·0	1·24
3. Away from Sau trees ...	10·4	2·28
Under Sau trees ...	10·0	2·08

Shade therefore reduces the pungency of tea. This fact is made use of in the production of green teas in Japan (where green teas are better liked if they show little pungency). Teas of very high value are produced by shading part of the garden with cloth.

The shading also improves the colour, a great point in a green tea. When black teas of good quality are desired it is clear that some care must be exercised in the use of shade trees. While benefitting the health of the bush when used in moderation over heavy shade will lead to loss of quality.

Apart from actual shade, lack of sunshine due to clouds was shown to have a similar effect on the tannin content of the leaf. In dull, overcast weather teas lacking in pungency are produced.

Effect of Manuring: Increases in crop are most easily produced by the use of nitrogenous manures. It is an observed fact, that other things being equal the more rapid growth induced by such manuring, produces a lowering of quality.

Bigger crops can however, be produced without increasing the rate of growth, by increasing the vigour of the bush so that it will support a larger number of shoots, and will allow closer plucking. It should be possible then to use manure to

increase crop without any loss in quality so long as it is accompanied by reasonable pruning and plucking. Hope analysed leaf from manured and check plots Heeleaka in 1910. He showed that while the very big flushes following the application of readily available manures like nitrates showed some diminution in total solids (and therefore presumably in quality), there was no appreciable difference following the application of equivalent quantities of slow acting oilcake. In these cases plucking and pruning were the same for manured and check plots.

By the mineral manures, phosphoric acid, and potash, it would appear that quality is rather increased than otherwise.

"Quality" districts always contain high proportions of these constituents in the soil. Good teas contain more potash and phosphoric acid than poor teas. In some few cases manuring with phosphates has led to noticeable improvement in liquors.

On the whole, then, we are of opinion that there is no fear of noticeable loss of quality from manuring, so long as the manures are well balanced, and pruning is adapted to produce a wide, healthy bush which allows close plucking. "Flat" plucking is also of assistance in producing the wide bush, since it allows no "running away" in the centre, and the outsides are relatively strengthened.

Variation with Season: The variation in tannin content with season can be traced from the curves facing page 57.

The curves are not exactly of the same form for both dark and light leaf varieties, but all the curves have the following features in common :—

(1) At the beginning of the season the tannin content is low, particularly in the very earliest pluckings. It is well known that the first flush does not make teas up to the average of the season.

(2) The tannin content is about its maximum during August and September and tends rather to fall off some time during October.

THREAD BLIGHT.

(Sterile mycelium.)

DARJEELING AND TERAI.—No reports were received.

JALPAIGURI AND DOOARS.—No reports were received.

ASSAM.—Specimens were received from one garden in Dibrugarh.

CACHAR AND SYLHET.—It was present in several gardens in both the districts. It was bad in one garden in North Cachar.

ROOT DISEASES.

Ustulina zonata.

DARJEELING AND TERAI.—Specimens were received from four gardens in Darjeeling.

JALPAIGURI AND DOOARS.—Specimens were received from one garden in Jalpaiguri.

ASSAM.—Specimens were received from Sibsagar and Golaghat.

CACHAR AND SYLHET.—Specimens were received from two gardens in North Cachar.

Rosellinia arcuata.

DARJEELING AND TERAI.—It was reported from one garden in Darjeeling where it was very serious.

JALPAIGURI AND DOOARS.—No reports were received.

ASSAM.—Specimens were received from two gardens in Dibrugarh.

CACHAR AND SYLHET.—It was reported from one garden in the Juri Valley.

This disease was also found on *Cajanus indicus* and *Indigofera dosua.*

Sphaerostilbe repens.

DARJEELING AND TERAI.—No reports were received.

JALPAIGURI AND DOOARS.—Specimens were received from one garden in Dooars.

ASSAM.—Specimens were received from two gardens in Jorhat and one in Dibrugarh.

CACHAR AND SYLHET.—Specimens were received from four gardens in Sylhet.

This disease was found on *Albizzia moluccana.*

Hymenochaete noxia.

DARJEELING AND TERAI.—Specimens were received from one garden in the Terai.

JALPAIGURI AND DOOARS.—Specimens were received from two gardens in Dooars.

ASSAM.—Specimens were received from gardens in Jorhat and Sibsagar.

CACHAR AND SYLHET.—It was found in both the districts. This disease was also found on *Cajanus indicus.*

Thyridaria tarda.

DARJEELING AND TERAI.—No reports were received.

JALPAIGURI AND DOOARS.—No reports were received.

ASSAM.—Specimens were received from Golaghat, Jorhat and Mangaldai.

CACHAR AND SYLHET.—It was present in several gardens in Luskerpur and South Sylhet.

Specimens were also received from a garden in Chittagong. This disease was also found on *Albizzia lebbek* and *Albizzia procera.*

A new disease was discovered in specimen received from Nowgong. The fungus has not yet produced any fructifications. It is interesting to note that a species of *Colletotrichum* similar to that which causes brown blight was found along with *Thyridaria tarda* on the root of a dead tea bush. It is under investigation.

NOTES.

Guano from Latham Island, near Zanzibar.—The following information concerning a deposit of guano appears in the Bulletin of the Imperial Institute, No. 2, 1920.

Latham Island is situated in the Indian Ocean, forty-one miles south-east of Zanzibar and twenty-eight miles east from the mainland of Africa. It is 350 yards long and 180 yards wide, and the surface is 10 ft. above spring tide level, but landing is bad and dangerous. According to the Director of Agriculture, Zanzibar, the central plateau of the island, is covered with guano to an average depth of one foot. A sample of this guano was sent to the Imperial Itstitute for examination last year. It consisted of an earthy phosphatic material, containing lumps of phosphate of lime. Plant remains, sand, etc., were also present.

The guano was chemically examined with the following results, which are shown in comparison with figures recorded for well-known typical commercial guanos from Peru and South Africa :—

		Peruvian guano.			S. African guano.	
		Present sample.	Guanape.	Chinchas.	Saldanha Bay.	Ichabo Island.
Total nitrogen ...	N	0·76[1]	11·0	16·09	1·41	...
Total phosphoric anhydride	P_2O_5	29·52[2]	12·25	...	24·52	11·19
"Available" do.	P_2O_5	19·10	...	9·29	...	...
Lime	CaO	35·36[2]	...	...	24·26	...
Total potash ...	K_2O	0 33	2·5	2·5	...	...
Organic matter ...	...	1·88	...	...	...	...
Moisture, on heating at 105°C.	H_2O	15·24	25·88	...	17·04	17·97

1. Including nitrogen present as :

   Nitrates, expressed as nitrogen pentoxide N_2O_5 1·19 per cent. of the original material.

   Ammonia, expressed as nitrogen pentoxide NH_3 0·015 per cent. of the original material.

2. Equivalent to :

   Calcium phosphate $Ca_3P_2O_8$ 62·78 per cent. of the original material.

   Calcium carbonate $CaCO_3$ 3·75 per cent. of the original material.

It will be seen from the above results the present sample bears considerable resemblance in chemical composition to the guano obtained from Saldanha Bay, South Africa, but that it contains less nitrogen and more phosphate than typical Peruvian guano.

It was considered by firms interested in guano that this material from Latham Island could not be profitably exported to the United Kingdom at the present time, on account of the high cost of freight. The pre-war price of such guano in this country was about £3 per ton c. i. f., and even now it would only realise about £8 to £9 per ton.

It may be possible to dispose of the guano in Zanzibar, or a market could perhaps be found for it in East Africa.

Guano represented by the present sample would be of value for manurial purposes, chiefly on account of the satisfactory percentage of available phosphoric anhydride (*i. e.* the portion soluble in a 2 per cent. solution of citric acid). In order, however, to make a complete manure the guano would require to be incorporated with materials containing more potash and nitrogen.

Mole Draining: In the January Number, 1921, of the Journal of the Ministry of Agriculture, there is a very interesting note on a particular form of drainage known as 'Mole Draining.' This aricle is also issued by the Ministry of Agriculture as Leaflet No. 356. Whilst this is not a form of draining that has been adopted in tea gardens yet the article is interesting and suggestive. It reads as follows :—

There is no doubt whatever as to the value of drainage, especially on heavy land. On land that is badly drained the best type of herbage can never be obtained, while at the same time the grazing season is practically limited to the drier summer months. At other seasons stock cannot be carried on such land without grave risk both of illness and disease to themselves and of lasting damage to the texture of the soil.

In the case of arable land, work is retarded and rendered difficult and expensive. Crops cannot be depended upon. They

have frequently to be sown out of season and are apt to fall an easy prey to various pests and diseases.

The present cost of laying down extensive systems of pipe drainage is very high, but on heavy clay soils quite as efficient, if not quite as permanent, drainage can be obtained at relatively little cost by the use of the mole plough. On such land most drains will last from eight to ten years and under favourable conditions even twice as long. The inclusive cost (about 50s.—65s. per acre) is often fully recovered in the increased crops obtained the first year.

Mole draining is not adapted to every kind of soil, but wherever heavy clay land, to which it is especially adapted, is to be found, it deserves, as one of the cheapest and surest methods of improvement, full and careful trial. On more friable soils mole draining may be successful, but in such cases there must always be a good fall and intermediate main drains should be provided. There should be few, if any, stones so large that they cannot be turned aside by the coulter; and the ground must not be too uneven, as the drain will naturally follow the inequalities of the surface. If the field is laid up in ridges and furrows the drains must follow the line of the furrows and not run across them.

As regards fall, if a field has a sufficient fall on the surface for a water furrow to run, there will be sufficient fall for the proper working of a mole drain. Less fall is required on a heavy plastic clay than on a more friable soil, where water standing in the mole would tend to make the walls fall in.

The mole plough consists of a round steel plug about three inches in diameter attached to the lower end of a strong coulter which is fitted to a suitable frame mounted on wheels. It is worked, like an ordinary steam plough, by cable and winding drum.

There are two methods of proceeding. Either the moles are first run and then the mains are put in, or the mains are first laid and the moles run over them. In either case the work must be carefully planned beforehand. If the moles are run first the mains should be laid with as little delay as possible. On lighter land and where the fall is slight it is better to lay the main

drains before running the moles, otherwise a heavy shower may ruin the work completely. The advantage of running the moles first is that they can be cleared out with a stick as the mains are dug and an outlet secured into the main. As a rule pipes are used for the mains and also for the beginning of each drain to make a good junction with the main.

Where the slopes drained by the moles are short, the mains may be laid with $2\frac{1}{2}$-inch pipes, but where the slopes are longer 3-inch pipes should be used. The longer the slopes and the steeper the fall the more numerous should be the main outlets; at any rate there should always be at least one for every three acres.

The moles are sometimes started from holes, or "eyes," into which the coulter, with the plug attached, is dropped; but often when the lie of the land and the lay-out of the proposed drains admit it, the mole is allowed to bury itself. If, for instance, the main runs parallel with the side of the field and not less than 14 yds. from it, the mole drain can begin at the surface and will have reached full depth by the time it crosses the line of the main.

The tunnel produced is very similar to a mole's "run," and if the subsoil is of the right texture and moistness, an efficient drain is obtained. The disturbance caused by the coulter itself is very small and as a rule the cut soon closes up. Even when a crop is being grown on the land the work may be done without causing any very serious damage, especially if done in dry weather and before the crop is more than a few inches high.

There should be a main drain along the bottom of the field: in the case of an uneven field main drains should be made along the hollows. For cutting the main drains, a drain-cutting machine, such as the Swedish "Revolt" excavator, will save a considerable amount of hand labour. As a temporary measure main drains can be made by the mole plough and connected with a boundary ditch, or the mole drains can be run direct into a ditch. In this case, however, they should be protected, by the insertion of pipes, for two or three feet from the outfall; but it is not advisable to do without a main drain. A number of mole drains running into an open ditch will require more labour to keep clean than is likely to be

available, and as some width of headland must generally be left for the engine to stand on, it is not always possible to run the moles direct into a ditch. Where it is desired to save expense, Faggot, or Bush Drains, as described in the Ministry's F. P. Leaflet No. 62, are sometimes used. Sometimes pipe draining is combined with bush draining. The main drain is dug about a foot deeper than the moles are to be driven, and filled in above the pipes with bushwood up to the level of the moles. Then this is put in before the moles are drawn; it should consist of twigs not more than 1 in. in diameter. The coulter will cut through these quite easily. When considering how deep to set the coulter of the drainer care should be taken to put it at the minimum depth of the mains, as these will of necessity be a few inches shallower in some places than in others.

A main drain should always have a cheap facing of brick or stone round the last pipe. This prevents damage and serves to mark the outfall.

The mole drains are usually made about 2 ft. in depth and about 5 yds. apart. Where the field is laid up in ridges or ditches the distance between the moles is usually determined by the distance between the furrows, but this is not always a certain guide, as the nature and lie of the land may require more drains. In fields where the water percolates to the subsoil very slowly, it is best to put in the mole drains fairly close, say about 3 yds. apart, and not deeper than about 18 ins. or 20 ins.

It is most important that a plan of each field should be kept showing the mains and their shallowest points. Such a plan will be useful in case the field should be moled again.

In Essex, where a good deal of mole drainage is performed annually, it is the custom for the tenant to carry out the work and the landlord to find the pipes for the main drains. In cases where the tenant leaves his farm after doing the work, compensation is generally given on a basis of three to six years.

Nitrolim.—(Calcium cyanamide): Changes taking place when mixed with fertilising materials. R. N. Harger. Journal of Industrial Engineering Chemistry, 1920, 12.

This article points out that when nitrolim (calcium cyanamide) is mixed with superphosphate in the presence of 5 to 10 per cent. of water the cyanamide content decreases rapidly, dicyandiamide being formed as one of the chief products of decomposition. In a note of this Journal published in 1919 it was pointed out that dicyandiamide has toxic properties to plants. Water alone can decompose calcium cyanamide slowly but dry superphosphate has no effect.

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In this case the figures obtained for tannin content do not correspond with what is known of variation of quality with season.

It would appear that if tannin is a great factor influencing quality, then quality should be highest during August and September. It is usually found, on the contrary, that there is a marked improvement in quality after the end of September.

Here some other factor must be so active as altogether to outweigh the influence of tannin. Factors likely to be active towards the end of the season are :—

(a) Increase in flavour, due to formation in greater quantity of the substances yielding aroma, which is very possibly related to lowering of the temperature during growth.

(b) Increase in quality, due to the improved atmospheric conditions for withering and fermenting as affecting both tannin and aroma.

PART III.

Having discussed the composition of the green leaf as plucked, it will be well to indicate how such knowledge as we at present possess may be used in the control of the successive stages of manufacture. In the manufacture of green tea the constituents of the green leaf are desired unchanged, the process being practically a drying process only with precautions against fermentive changes. In black tea we desire flavoury decomposition products, and a development of full aroma.

Withering : In the leaf-house two kinds of change are going on—one merely physical, and the other chemical. The physical change is the loss of water by evaporation, and is complete when the leaf has lost its turgidity and become sufficiently flaccid (or soft), to bend without breaking, so that it may be rolled without being unduly smashed up, and so that there will not be an undue loss of juice during the rolling.

The time required for this change to become complete depends upon the temperature, the dryness or moistness of the atmosphere,

and the presence or absence of wind. It is known that if this change is either too rapid or too slow, then although the leaf may be mechanically ready, it will not make good tea. Mann explained this as being due to the necessity of time for the increase in quantity of an oxidizing enzyme during withering. There appears to be more than that in it.

Tannins occur in the leaves of many plants, usually in combination with another substance (often a sugar). This compound is built up during the life of the leaf. After the death of the leaf the process is reversed, and under the influence of a hydrolysing enzyme the compound is decomposed by the water in the leaf. The freed tannin then combines with oxygen from the air under the influence of an oxidizing enzyme (oxidase) to form brown compounds.

With respect to tea this subject is still under investigation, but there appears at present every reason to believe that similar reactions occur in a plucked tea leaf.

It will have been noted that these reactions depend upon a loss of vitality of the leaf cells, and this loss of vitality is obtained by drying.

During withering, then, we require loss of vitality by drying, and then sufficient time for the hydrolyzing enzyme to act.

Should the rate of drying be too slow the leaf will not loose vitality sufficiently rapidly, on the other hand if drying is too rapid, the hydrolyzing enzyme will not have time to do its work.

As far as may be judged at present, in properly withered leaf the hydrolysis of the tannin compound should be nearly complete, while the oxidation to brown compounds should not have proceeded to any extent. That is, the leaf should still appear green, although on holding it up to the light a certain amount of browning will appear, particularly in the ribs, and the leaf must retain sufficient water to be still soft.

Under-withered tea will produce teas of great pungency, but with little colour or thickness of liquor. Over-withering produces

thick liquoring teas, of deep colour, but little pungency. If, however, withering is very much too slow or too rapid, teas having no good points may be obtained. In practice best results appear to be obtained when the leaf reaches the right stage in about 18 to 21 hours.

Under certain climatic conditions it is not always easy to arrange for this time.

In the early part of the season, particularly when there are hot dry winds, leaf may become brown and too dry in a night.

In such weather it is extremely difficut to make good tea, and the poor colour obtained is always noticeable. Conditions would certainly be improved by the use of side curtains for the leaf-houses, which would then contain the leaf in as still an atmosphere as possible. Rather thicker spreading, also, should then be used, although the teas will lose something in evenness.

In saturated atmospheres such as commonly occur in the Duars during the rains the difficulty is to get sufficient drying for loss of vitality in reasonable time.

In view of the above theory of withering, it appears that artificial drying should be applied at the *beginning* of the wither. When sufficient loss of vitality by drying has been obtained, the required reactions would then go on, although no further drying takes places. Previously it has been recommended that the drying should be at the end of the wither. This is still a matter for experiment in practice, and offers a very useful field for experiment in the factory. From theory it would be expected that when the atmosphere is nearly saturated, and it is necessary to use fan withering lofts, the following procedure should give best results. As soon as the leaf is placed in the loft, it should be subjected to the draught of hot air until dried to not quite the right physical condition; the fans should then be stopped so that little further drying takes place, and the leaf then left for the chemical reaction to proceed. This reaction may be judged to be complete when browning of the ribs of the leaf has occurred, while the rest of the leaf is still green. The drying may be regulated by experience so

that the total time of wither is about 18 hours ; although, since the temperatures will be high, less time may be found to be necessary. The action of the hydrolyzing enzyme is most rapid at 90°F.

Some precaution will be necessary, whether withering with or without fans, to obtain an even wither. If some leaves, or parts of leaves, are prevented from drying as rapidly as the bulk, then the undried parts will not have lost vitality sufficiently to colour at the same rate as the bulk during fermentation, and patchy teas will result. The balance between fermented and unfermented tannin may still be good so that liquors may possibly not suffer ; but such green patches always prejudice a buyer unfavourably, and in any case the rolling and fermentation of unevenly withered leaf are very much more difficult to control.

To obtain even withering several points need attention. Thin spreading will assist even withering. Leaf in the middle of a thick layer clearly cannot dry at the same rate as leaf on the outside.

The lower surface of a leaf dries more quickly than the upper surface. For both reasons the old practice of occasionally turning the leaf by hand is recommended. Bruising of the leaf by careless handling must be avoided.

Where fine teas are expected many managers prefer to wither on flat "chungs" made of split bamboo covered with Hessian cloth, rather than on galvanised iron wire-netting racks. Several reasons can be given for this preference.

Shoots that hang down through the wires, become rapidly over-dried and spoilt.

Then in a leaf-house, racks are usually spaced much closer together than are chungs. This gives less working space, and in consequence leaf is often not spread so evenly, and is more liable to become bruised and damaged in handling. Owing to the closer spacing, also, there is less free circulation of air, and leaf on the inside racks does not wither at the same rate as that on outside racks. The mugginess of the atmosphere in the centre of a rack-house is often noticeable on a windless day. The Hessian

cloth used for covering either chungs or racks must be kept clean as it may become a source of infection by undesirable micro-organisms.

Rolling: In the old days leaf after withering was rolled by hand, at that time great importance was attached to getting a "good twist" on the leaf, whereby the dried tea assumed a wiry appearance.

For a long time after rolling-machines had superseded hand rolling in nearly every factory, "good twist" was a point looked for in good teas, although now-a-days less importance is attached to it.

Now before the fashion was set, there could have been no reason why teas of any particular or peculiar appearance should be preferred. It must have been the case that teas showing "good twist" were generally noticed to be teas of good quality.

To start with, improperly withered teas will not take a twist, and as has been shown, this provides an excellent reason for believing that proper withering is essential for production of the highest quality. But there is more than that in it. Appearance was not the main object of manufacture, but the production of colour and flavour. By hand rolling, the production of tightly twisted rolls would be the most efficient method of damaging the maximum number of cells. A large number would be broken or killed while those still unbroken would have a large part of the cell sap squeezed out and so be reduced in vitality. We suggest, in fact, that the production of tightly twisted leaf gave the most even and complete reduction in vitality of the cells.

Under "Withering" we have shown that reduction in vitality is necessary for the changes desired in producing black tea leaf. Only when the leaf begins to die, are the coloured fermentation products of tannin produced under the influence of the enzymes present.

The young and delicate portions of the plucked shoots will lose their vitality more easily, and will ferment more rapidly than the older coarser portions.

Withered leaf is put into the rollers and rolled for a time, varying within wide limits (15 to 40 minutes). This first roll is usually carried out without any pressure from the weight cap, in order to avoid undue damage to those more delicate portions of the shoots. It is desirable, particularly, to retain the golden colour of the tip. The leaf is then put through a green leaf sorter. The fine leaf is then usually taken direct to the fermenting room, while the coarse leaf is put back into the roller. This second roll is given with more pressure, frequently with as much pressure as possible.

Often this leaf is again sifted and the coarse leaf rolled once more.

It will be seen that the rolling follows up the withering and effects a still further reduction in vitality, and the repeated rolls attempt to reduce the vitality of all parts evenly. Heavy rolling can so reduce vitality as largely to counteract insufficient or uneven withering, particularly when very fine teas are not expected.

The rolling, of course, does more than reduce vitality. Sap is squeezed out of the cells and rolled over the surface of the leaf. Leaf which went into the roller dry on the outside, comes out in a moist condition. After this point, micro-organisms can very materially affect the condition of the leaf. If undesirable bacteria (which do make their appearance at certain times of the year) are present in large numbers, undesirable products may be obtained. The leaf may become sour or acquire a musty or other undesirable smell.

At this point any desirable micro-organisms which may be present will begin to act.

The sap also is now exposed to the air, and the effect of this is to render more active the oxidizing enzymes which cause the formation of coloured compounds. Not only that but the greater the number of broken and damaged cells, the more easily extractable by boiling water will the soluble matter of the dried tea become.

The harder the rolling, therefore, the thicker and darker may the liquors be expected to be. The time of rolling, there-

fore, requires very careful consideration. For the second and succeeding rolls, when there is no tip or fine leaf to be damaged, it may be rolled for a very long time, but the pressure should not then be so great as to cause red juice to run out at the bottom of the roller, for this means the loss of liquor. Where long rolling cannot be given, then greater pressure must be used. The juice which then runs out, is commonly found to reduce quality if added to the leaf from which it came before that goes to the fermenting room. It produces flat teas. This red juice is already fully fermented when it leaves the rollers, and must also be very rich in oxidizing enzymes. Further fermentation not only spoils it, but to some extent the leaf to which it is added also.

This ready juice, therefore, should be mixed with leaf which has just left the fermenting room, and is being taken into the drier.

In the roller, leaf is of course fermenting, and the temperature should therefore be as nearly as possible the optimum for fermentation. During rolling temperature rises, particularly if much pressure is used. This is a great objection to the system by which the leaf is kept in the roller for nearly the whole of the fermentation time.

The system under which the leaf is rolled several times and removed and sifted between each roll is better from this point of view, since the leaf is allowed to cool. The finer leaf, also, which does need so much rolling, avoids being over-rolled.

On the other hand continuous rolling has advantages. Undue pressure may be avoided, and the rolling still be thorough. The leaf also is kept stirred so that no part becomes more oxidized than another, and it avoids the dangers of draughts and excess of air.

Fermentation: After withering and rolling are complete, the vitality of the leaf cells is very low indeed. The velocity of the reactions concerned in the making of black tea is the greater the lower the vitality of the leaf cells. The leaf therefore now changes its colour and other characteristics with great rapidity.

The colour produced is an index to the quality of the product. When a bright, coppery red, fine tea is made. When the colour becomes dull and brown, liquors will be soft, and although they may be thick and dark, they will not be bright.

It seems probable that the first colour is associated with the presence of "tannin red," while the latter is due largely to the presence of excessive quantities of "tannin brown" although undesirable micro-organisms may here play a part.

While we cannot yet completely control this stage of the manufacture, the following have been shown to be points of importance:—

1. The leaf must not be allowed to dry further. This is of particular importance during the hot dry days of the early season. When the hot dry air is assisted by a draught nearly black leaf is obtained in patches. This may be prevented by covering the fermenting leaf with a cloth. Mann protests against the use of such cloths. There is no doubt that they may easily become sources of infection by undesirable bacteria, but if kept scrupulously clean by boiling, there is no objection to their use. They are probably unnecessary in the rains, when the atmosphere is damp.

Even in the rains, however, draughts should be guarded against. Even if saturated with moisture, they still bring fresh oxygen, and excess of oxygen appears to be undesirable.

2. During the rains draughts may be prevented by hanging wet cloths round the walls of the fermenting room. This also has the effect of keeping the temperature down.

It is well established that the fermenting leaf must be kept at about 82°F. Any considerable rise means loss of quality, at temperatures greatly lower fermentation is too slow, but good results are obtained down to about 75°F. if the time of fermentation is increased.

At low atmospheric temperatures, leaf may be spread thicker so as to use the heat generated during fermentation to raise the temperature of the mass. At higher temperatures spreading must

be thinner, though there is no advantage in spreading thinner than about two inches.

3. The time of fermentation will depend upon the previous withering and rolling, and upon the temperature and the activity of the enzymes present. It averages approximately 3½ to 4 hours, but in practice varies considerably.

The best test for complete fermentation is a practised nose. When the leaf has produced its maximum aroma and just begun to fall off slightly, it is ready to be fired. The colour of the fermenting leaf is also a useful help. It is not correct to wait until all the green patches have changed colour. The ideal is an even bright copper colour, but if through uneven withering or rolling some parts have escaped sufficient loss of vitality, then the bulk of the leaf is spoilt by the time the last green patch is gone.

A better balanced liquor is obtained by stopping fermentation whilst the greater part of the leaf is brightly red (even though patches are green), rather than by waiting till the whole is brown coloured.

4. An important point (which is not yet fully explained) is that an old fermenting floor produces better tea than a new one, and a cement floor gives better results than tiles or glass. This is particularly noticed on gardens making high quality teas, although it appears to make little difference in factories making common tea. Mann came to the conclusion that no micro-organisms other than harmful ones were present in fermenting tea, and therefore recommended that fermenting floors should be sterilized, and in many factories it has become the practice to regularly steam floors or to wash them with permanganate.

We do not recommend that such thorough cleaning should be altogether abolished, but that it should be used with discretion. So long as good teas are being made, then let well alone, and wash only with cold water and a broom or brush ; but as soon as unsatisfactory teas appear, particularly if "tainted," or of a bad colour, then sterilize by steaming or otherwise.

Firing: The drier raises the temperature of the leaf sufficiently to stop fermentation, and then removes water so as to leave the leaf too dry for further action when it has cooled.

Mann showed that a temperature of 150°F. was necessary to stop fermentation, and that it could be 180° F. without harm.

These are temperatures in the leaf which is kept cool by evaporation. The machine temperature must therefore be higher.

During the drying some tannin is decomposed, and also a large proportion of the essential oil is evaporated with the steam evolved. Both these losses are minimised by firing at a low temperature.

Some machines are arranged with a bye-pass so that hot air direct from the furnace can be turned on to the topt ray to stop fermentation. This allows a lower firing temperature for the remaining trays.

Essential oil is very volatile in steam, but very much less volatile in hot dry air. It is therefore very necessary that the leaf shall not be steamed, or aroma will be very seriously reduced. To obviate this a large supply of hot dry air must be forced through the leaf so as rapidly to dilute the steam, and the leaf must be spread thinly. Where flavour is the first consideration a machine temperature of 200°F. is recommended. For pungent teas temperature may be about 200° to 220°F. and for thick liquoring teas the temperature may be somewhat lower 180° to 200° F.

These are temperatures for the first firing. In subsequent machines it is of not so much importance that the temperature be kept down, although high firing is to be avoided until the leaf is nearly dry, otherwise a dry casing is obtained when the core of the leaf is still wet. This not only hinders drying, but renders leaf liable to be accepted as dry, which subsequently becomes soft as moisture from the core disseminates through the dry crust. For the second firing temperatures may well be kept at 220°F. These temperatures should be carefully controlled, and in order that control shall be efficient it is strongly recommended that

recording thermometers should be attached to each drier, or at least to those in which the first firing is done.

Leaf as it leaves the fermenting room occupies so much space that it is more convenient to complete the drying in two operations, the first machine drying the leaf to about 12 annas, the 12-anna-fired leaf (now reduced in volume) is then put through another machine.

This method appears to result in very little loss of quality. It is important, however, that the 12-anna leaf must not lie about in heaps while still hot. It should immediately be put into the second machine; or where this is not possible, it should be spread out and cooled.

After the leaf has been completely fired it should be cooled rapidly and put into the air-tight bins so that it absorbs very little moisture from the atmosphere. Bins should be deep, as this will help to prevent absorption of water.

Sorting: This is a purely mechanical operation. The tea is sorted to suit market requirements at the time. Being purely a commercial problem it calls for no comment here.

Packing: Only one aspect of this question need be dealt with here, the moisture content at the time of packing.

Teas after sorting are usually kept in the factory till sufficient is collected to make a break, when the whole is bulked.

Unless the tea has been kept in good air-tight bins it will have absorbed moisture, and it will then generally be necessary to final fire or "gap" it before packing.

Final firing undoubtedly lowers quality somewhat. and should be avoided if possible by keeping tea in air-tight bins. However, if the tea is to exhibit keeping qualities, it should certainly not be packed with a moisture content above 9%, and would be better about 7%.

Work by Hope and Carpenter in Assam, and by Welter in Java led to practically the same conclusions. Best results are obtained by packing tea at about 6 to 7% moisture content.

With moisture contents below 5% or much above 7% the tea does not keep. In either case tannin is lost, while with the higher moisture contents there is danger of the tea becoming mouldy. It is not possible to say whether tea should not be final fired without a definite determination of its water content.

Where it is considered necessary final firing should be carried out at low temperature (180°F.) in the shortest possible time.

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To distinguish this particular class of soil we propose to term it the

SOIL SURVEY.

Notes on the New Alluvium of the Dooars.

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In a previous note (*Quarterly Journal*, 1921, Pt. IV) Carpenter dealt with the soil types occurring on the Red Bank areas. The present note gives a brief account of the newer alluvial soils which make up the lower lying tea lands of the Dooars.

Mal District. In the Mal District the Red Bank forms a rough triangle with its boundaries including Lower Fagu, Meenglass, Nedeem (out-garden of Sylee) to the north-west and west, Rungamuttee and part of Hahaipatha to the south, and Toonbari with parts of Soongachi and Nakhati to the east and north-east. Outside this area the Mal District consists of newer alluvium. West of the Red Bank area the soil is remarkably even in character, and is an extremely interesting type of soil. It is characterised by a sand content between 50% and 80% (coarse sand nearly always being in excess of fine sand) and a clay content averaging about 3%, being sometimes under 1% and practically never above 8%. The place of clay (which is generally the "binding" constituent of a soil) is apparently taken by colloidal organic matter which is abnormally high for such light soils. "Loss on ignition" averages about 6%, being always above 4% and often up to 8%. The "soluble humus" or "Grandeau" organic matter is also remarkably high. The soils are chemically very rich and show a very high acidity by whatever method that is measured.

Mann apparently included all the Dooars new alluvium under the term "grey sandy loam." These particular soils have so little clay or even fine silt that they certainly cannot be called "loams", and the colour is often a reddish rich dark brown—almost chocolate. To distinguish this particular class of soil we propose to term it the

"*Mal Sand*". Similar soils are found in small areas in other parts of the tea districts of North East India. This sand is certainly much older than other soils of the new alluvium. It has not accumulated its organic matter and acidity in a short time. It is often very undulating, and near the hills forms high plateaux through which the rivers have cut very deeply.

At Upper Fagu similar soils occur, raised well above the level of the Red Bank, which have an organic matter content of 14%, a figure usually only found so great in bheel soils. It is possible that similar soils occur elsewhere in the hills whence they are washed down to enrich the Mal Sands.

The Mal Sand occupies a sweep of country from the Teesta River as far east as a line through Sylee, Sissubari (Good Hope), Kumlai, Baintguri, and is found again eastwards, in the southerly part of the Chalsa District.

West of the Teesta at the only garden from which analyses are available (Dangua Jhar) very similar soils are found.

The commonest soil type among the Mal Sands is the 1, 2, 4, 3, 5, which preponderates at Bullabarrie, Sylee, Leesh River, Ranicherra, Good Hope, Bagracote, Baradighi, Ellenbarrie and is also found on other gardens.

Analyses of light, average and heavy examples of the 1, 2, 4, 3, 5 type are given below :—

	Light.	Average.	Heavy.
1. Coarse sand	67	55	33
2. Fine sand	17	19	28
3. Silt	2	8	11
4. Fine silt	5	10	13
5. Clay	0·1	4	16
Loss on ignition (organic matter)	6·7	4·6	4·9
Soluble humus (Grandeau Organic matter)	4·4	2·1	2·4
Acidity	3430	2500	2270

Less common types, examples of which are given below also occur. It will be noticed that these are closely related to the 1,2,4,3,5 type.

Soil Type.	1,2,3,4,5.	1,2,3,5,4.	2,1,3,4,5.	2,1,4,3,5.	1,4,2,3,5,
1. Coarse sand	35	47	22	26	62
2. Fine sand	20	25	45	37	10
3. Silt	15	11	15	10	4
4. Fine silt	13	4	8	12	15
5. Clay	7	5·5	3	9	2
Loss on ignition (Organic matter)	6·0	5·7	4·1	4·7	6·0
Soluble humus (Grandeau) Organic matter)	2·5	3·1	3·2	1·6	2·9
Acidity (modified Veitch Albert)	2500	2690	1600	1700	2400

It will be noticed that all these types have in common the following physical characteristics :

(1) Very high percentage of sand :

(2) Low clay content.

Such coarse-grained soils can lift water by capillarity through a small height only—say, 10 feet. On such soils liability to suffering from drought is therefore very great during the dry season, particularly in the Dooars where early rain is not commonly obtained. In order that tea may be safe from drought, it is therefore necessary that the distance between the deepest roots and the cold weather water-level must be less than 10 feet. To ensure this, it is essential that the depth of the root shall not be limited by a high water-level in the rains ; and to keep the rains water-level down, deep drainage will be required, except on low-lying spots where the cold weather level remains high.

Close drainage, however, is not only unnecessary but undesirable, since it dries out the soil in the dry season.

The necessity for deep roots should also be borne in mind, when deciding the early pruning treatment of tea on such soils. Bushes should be allowed a good run before pruning or plucking in order to be allowed to force down a deep straight root.

Of the Mal Sands those with the higher clay content will usually be found to do better, merely because they will be able to lift water by capillarity from a greater depth, while the rate of movement of water through the soil being slower, the rate of drying of the soil will be reduced. Where, as is nearly always the case, the clay is very low, high percentages of fine silt and organic matter (much of which is of a colloid nature) will assist to increase the power of lifting water by capillarity.

It is noticeable that wherever this very light type of soil is found, there serious attack by mosquito blight was early noticeable ; and it is very probable that this may be associated with weakening of the bush by suffering during droughts.

In only two cases, both far removed from sources of infection, are such soils known to be unattacked by mosquito.

Just below the Red Bank area, heavier soils are found, for example, at New Glencoe, and the lower parts of Hahaipatha and Sungachi, soils of the 4, 2, 3, 1, 5 ; 4, 1, 3, 2, 5 ; and 3, 1, 5, 2, 4 types are found.

To the south also the soils begin to get heavier. At Oodlabari for example while the soil type is still 1, 2, 3, 4, 5, the clay content rises from an average of about 3% over the greater part of the district, up to over 9%. At Baintguri also the clay content has risen, in this case sufficiently to exceed the fine silt, so that the soil type becomes 1, 2, 3, 5, 4.

As far south as Nowera Nuddy while sandy soils do occur, much heavier soils show, for example, the 2, 4, 3, 1, 5 and the 4, 2, 3, 1, 5. These belong more properly to the grey sandy loams, and are clearly much newer deposits than the Mal Sands, since they are much less acid, contain considerably less organic matter, and are chemically less rich. For example the loss on ignition and "soluble humus" are only about 3·5 and 1·3 respectively, while acidity is

about 1300. Physically, however, these soils containing little coarse sand or clay are probably the very best for tea, and their chemical properties may be improved by art.

At Ellenbarie there occurs a patch of whitish silt, overlying the normal Mal Sand of the garden. It only occurs in the low part of the garden near the river and even there mainly fills up hollows. This soil is of the 2, 3, 4, 5, 1 type.

It clearly bears no relation to the normal soil of the district but is a much newer deposit, similar to some of the soils found at Nowera Nuddy, and also to soils found in the Daina Toorsa and particularly the Toorsa Jainti district. This soil is characterised by low acidity and low organic matter content.

Chalsa District: This is almost entirely a Red Bank district. To the west the Red Bank falls steeply to the Neora river. To the east occur strips of soil along the banks of the Murti, below the Red Bank, which have been more recently deposited by that river.

Such strips occur at Yong Tong, Chalsa, and Killcott.

At Yong Tong and Chalsa the soils are clearly much newer deposits than the Mal Sands.

At Yong Tong soil of the 1, 3, 2, 5, 4 type is accompanied by 60% small stones consisting largely of unweathered shaly sandstone.

Organic matter and acidity however are high, the soil has many of the characteristics of the Mal Sands and is probably from a similar source. The same type is found further down the Murti at Chalsa. Here the percentage of stones is only 18%, while organic matter and acidity are still higher than at Yong Tong. Still further down the Murti, at Killcott, the percentage of stones becomes only 7% and the soil is of the type 1, 2, 4, 5, 3. The acidity and the organic matter are high, the clay fraction forms less than 6% and the soil as a whole bears a very marked resemblance to the Mal Sand.

South of the Red Bank absolutely typical Mal Sand occurs. From the lower part of Sathkya we have two examples of the 1, 2, 3, 5, 4 type. Although the clay slightly exceeds the fine silt

(as at Baintguri), the clay is only about $3\frac{1}{2}\%$ and the sand exceeds 70%. Organic matter and acidity are very high.

Examples of the very closely related 2, 1, 3, 5, 4 type also occur at Sathkya.

Further south at Baradighi the soil is of the characteristic Mal Sand type 1, 2, 4, 3, 5. Acidity and organic matter are very high and the soil resembles that of the Mal District in every respect.

Representative analyses of new alluvium of Chulsa District.

(Note resemblance to Mal Sands).

Tea Gardens.	Yong Tong.	Chulsa.	Killcott.	Sathkya.	Baradighi.
Soil type.	1,3,2,5,4.	1,3,2,5,4.	1,2,4,5,3.	1,2,3,5,4.	1,2,4,3,5.
1. Coarse sand	51	34	41	62	55
2. Fine sand	11	22	30	16	31
3. Silt	14	23	5	9	1·5
4. Fine silt	6	4	12	1	3·5
5. Clay	9	10	6	3	0·5
Organic matter (Loss on ignition)	6·5	6·2	5·5	7·5	6·5
Soluble humus (Grandeau organic matter)	3·0	3·6	2·0	4·3	3·1
Acidity	1780	3420	2910	2840	2150

Nagrakata District.—The Nagrakata District also is mainly occupied by a block of Red Bank soil practically as far south as the railway.

To the west there is a flat at Hilla below the Red Bank along the bank of the Jiti River, but no analyses are available. To the south, sandy soils both of the Mal type and of the newer deposits of grey and white silts and silty sands occur.

The sandy soil at Grassmore generally is of the Mal type. The single analysis available shows the soil to be of the characteristic 1, 2, 4, 3, 5 type. While in other respects the resemblance to the Mal Sands is complete this example has a clay content about 10%, much higher than is usually found in the Mal District.

To the south the Jaldhakar and Daina rivers approach each other very closely, before joining. Between them is a strip of land which clearly has been deposited by these rivers within comparatively recent times. The soils are whitish or grey in appearance, and probably represent the kind of soil described by Mann as grey sandy loam. On this strip are the gardens Tondoo and Bamandanga.

As they must have been laid down at different times by flood waters moving at various rates, so the soils vary in physical composition. The water was never stagnant, so that clay is generally conspicuous by the small proportion in which it occurs. Coarse sand also is seldom present in quantity since the flood water rarely travelled fast enough to carry coarse sand in suspension. Fine sand however generally forms a great proportion of the soil.

The lightest type found is the 2, 1, 4, 3, 5 and the heaviest 4, 2, 3, 1, 5.

The average soil would appear to be 2, 3, 4, 5, 1. The type 3, 2, 4, 5, 1 and related types also occur. The subsoils are generally lighter than the top soils, the coarser particles having been dropped first.

Representative analyses of New Alluvium of Nagrakata District.

Tea Gardens.	Older alluvium resembling Mal Sands.		Very recent alluvium (grey sandy loam.) Note low sol. humus and acidity.				
	Grass-more.	Cheng-mari.	Tondoo and Bamandanga.				
1. Coarse sand	32	37	1	4	26	4	1·5
2. Fine sand	24	12	20	30	39	46	62
3. Silt	11	12	23	33	14	23	17
4. Fine silt	16	15	36	23	15	21	10
5. Clay	10	13	15	6	2		
Organic matter (loss on ignition)	7·5	10	5·5	3	3	6	9·5
Soluble humus (Grandeau organic matter)	.....	4·1	.....	.....	0·9	1·3	0·7
Acidity	.....	3100	.....	.....	1100	990	840

Dina Toorsa District. The district as a whole is marked by very great variation of soil even over small areas. The comparative regularity of soil type seen in the more easterly districts changes to a collection of patches of soil physically unrelated to each other.

The only feature common to any large number of soils of the district is that all five soil fractions are generally well represented. One very seldom finds soils with any one of the five fractions present in either excessively great or excessively small quantity.

That is to say the soils are distinguished by comparatively even grading.

The district is more gently and evenly sloping, less undulating, and has been much more subjected to irregular new deposits from rivers and floods than the Western Dooars.

On the whole fine silt forms the largest fraction of the average soil, while clay occupies a prominent position in the analyses of a few gardens only. Fine sand is very commonly an important fraction, while coarse sand is frequently found in quantity over small areas.

With the exception of patches of very new deposits which are unsuitable for tea, and of less new deposits on which tea is difficult to establish, the district on the whole is very fertile. The less fertile patches are distinguished by extreme deficiency in organic matter as determined by Grandeau's method (soluble humus).

For convenience the district may be considered in three areas (1) The Daina to the Rehti; (2) East of the Rehti up to the Hantapara plateau; (3) the Hantapara plateau.

Daina to Rehti.—Just across the Daina, for example at Red Bank Tea Estate, the soils found are of the same types as are found further west.

The average soil is the very rich humus-sand such as forms the greater part of the Mal District. The only analysis available is of the very light 1, 2, 3, 4, 5 type. Probably the rather heavier 1, 2, 4, 3, 5 also occurs as in the Mal District. Rising gently above

this sand are low teelahs of undoubted Red Bank soil of which no analyses are available.

It is possible that the clay found in the soils immediately south of this area, has arisen from erosion of Red Bank soils.

Probably similar soils occur on immediately neighbouring gardens which have not been sampled.

At Red Bank Tea Estate appears a patch of infertile new white soil such as is frequently found east of the Rehti. This has clearly been deposited very recently by one of the streams of the Daina. The dark fertile sand frequently appears as "islands" slightly above the level of the infertile white sand.

The Daina and the Rehti, although afterwards diverging, rise very close to each other in the north and between them no other river comes direct from the hills. With the exception of the one patch mentioned. therefore, infertile new deposits are not found within this area, since such deposits apparently come direct from the hills.

Starting from north to south we find the soil varying without regularity.

At Chamurchi two distinct types of soil occur, the lighter 2, 4, 1, 3, 5 and the heavier 4, 3, 2, 5, 1.

Choonabhutti averages the 4, 3, 5, 1, 2 type which is related to the heavier type at Chamurchi. At Choonabhutti the following types also occur 3, 4, 1, 2, 5 and 4, 5, 3, 1, 2.

At Hortalguri (New Dooars) the very unusual silt-sand type 3, 1, 2, 5, 4 occurs over a large area, and the related types 3, 2, 5, 1, 4, and 3, 5, 2, 1, 4 occur again to the south-west at Rheabari. These are among the few cases in this district where one of the soil fractions (in this case fine silt) is present in remarkably small quantity. The other unusual character shown by these soils is that silt is present in greater quantity than any of the other fractions.

Due south of Hortalguri at Palashbari we have soils, absolutely unrelated to the Rheabari soils, of the sandy types 1, 2, 3, 4, 5 and 4, 1, 2, 3, 5 the latter being related to the 4, 1, 2, 5, 3 found

westward at Lakhipara. This Lakhipara soil however contains 17 % clay, and is distinctly a loam and not a sand, while the average soils of Lakhipara are still heavier, such as the types 4, 2, 5, 1, 3 and 4, 5, 3, 2, 1.

South of Lakhipara we have the very similar soils of Gandrapara averaging 4, 5, 3, 2, 1, the heaviest being 4, 5, 3, 1, 2 and the lightest 1, 4, 2, 5, 3.

East of Gandrapara on the gardens of the Banarhat Company occur light and light medium soils mainly of the 1, 2, 4, 5, 3 or closely related types *e. g.*, 1, 2, 4, 3, 5 ; 1, 2, 3, 4, 5 ; 2, 1, 4, 3, 5 ; heavy medium soils 4, 2, 1, 5, 3 with related types 4, 2, 1, 3, 5 and 2, 4, 1, 3, 5, and 1, 4, 5, 2, 3 ; and one example of a heavy clay soil 5, 4, 2, 1, 3.

Further south at Binnaguri occur soils of the very heavy type 5, 4, 3, 2, 1 with related types 5, 4, 3, 1, 2 ; 5, 4, 2, 3, 1 and 4, 5, 3, 2, 1 together with sandier soils 1, 5, 3, 2, 4 and patches of very light soil of the 1, 2, 5, 4, 3 type overlying stones.

A little west of Binnaguri Station the railway makes an abrupt turn and then runs a little north of south-east. Below this line the soils show a distinct change. A line through Lakhipara, Gandrapara, Binnaguri goes mainly through heavy soils. The soils southward become sandier, the predominant types being 1, 4, 2, 3, 5 at Huldibari, 1, 3, 5, 2, 4 at Telipara, while from Gairkhata we have a single analysis showing a soil type 1, 2, 5, 3, 4. It is in this area that streams arise, and the assumption is made that they have been running under the more northerly heavy surface soils, through easily premeable stony and sandy subsoils, till they arrive at the flatter and more sandy land.

If this is true, the subsoils north of the railway must be very permeable to water, and this fact might be made use of in the drainage of the gardens. "Blind" drains, so long as deep enough to reach the natural underdrainage, should be all that is necessary. If the permeable subsoil is too deep to be reached by drains, then it may be possible to drain into "sumps," which empty through the subsoil, as the underground rivers are presumed to do.

East and south of Gairkhata the land is flat, cut up by many streams, and mainly under rice.

The second area from the Rehti up to the Hantapara plateau is still largely under jungle, and few gardens have been systematically sampled. Very many of the samples received have been sent in because tea has done very badly on certain patches, and these bad patches only have been analysed.

The infertile patches are concentrated in this area which is cut up by many rivers and streams direct from the hills. They generally occur as heavy silts, the 4, 3, 2 type with the related 4, 2, 3 ; 3, 2, 4 and 2, 3, 4 being common, but cases of 2, 1, 3 and even the very sandy 1, 2, 3 occur. Whatever the heaviness of these soils they are always white or grey in colour, alkaline in reaction, and very deficient in organic matter. Here it need only be pointed out that they are clearly new diposits of material straight from the hills, occur among the tea districts proper in patches only, and do not represent the greater part of the gardens on which they are found.

In the Daina-Toorsa district examples occur so widely distributed as Red Bank Tea Estate, Dheklapara, Jaybirpara, Makrapara, Dalmore, Nangdala. Further south occur patches which though not alkaline, are of low acidity and low organic matter content. They are of similar appearance but have become darker. These patches grow tea but not with the luxuriance of the more normal soil of the district. These patches are probably of similar origin to the more northerly alkaline patches but have been longer *in situ*, while the normally fertile acid soils of the district, characterised by a high content of organic matter, may be of similar origin but have been subjected to washing by the heavy rainfall, and have subsequently accummulated jungle residues, over a very long period.

The normal soils of the districts have not yet been very thoroughly sampled.

At Bundapani the sandy silt types 2, 1, 4, 3, 5 and 3, 2, 1, 4 5 are in evidence.

From Nangdala we have a single example of the type 2, 4, 3, 5, 1. This and allied types, where the percentage of either clay or coarse sand is small, appear to be the characteristic soils of the area. Having little clay, little resistance is offered to passage of water through the soil, whether to allow excess water to sink away in the rains or to raise water from the subsoil during a drought. The smallness of the quantity of coarse sand on the other hand saves the soil from excessively rapid movements of water, so that the soil is not dried out to a great depth during a drought. Soils of this character are probably of the ideal physical composition for tea. They are very much in favour for fruit in Europe.

For want of a better term, soils of this character may be termed "silt loams."

Considerable areas of the following gardens give average analyses of "silt loam" types.

Birpara	...	4, 2, 3, 5, 1
Demdima	...	2, 4, 3, 5, 1
Dalgaon	...	3, 2, 4, 1, 5
Dalmini	...	2, 3, 4, 5, 1
Sarugaon	...	2, 3, 4, 5, 1

On the above gardens examples of the following soils also occur.

Birpara	...	2, 1, 4, 3, 5	4, 1, 5, 2, 3
Demdima	...	4, 3, 5, 2, 1	
Dalgaon	...	3, 2, 1, 4, 5	2, 1, 3, 4, 5
Dalmini	...	4, 3, 2, 5, 1	

At Ethelbarie the soils are generally of the much lighter type 2, 1, 4, 3, 5 but the "silt loam" type 3, 2, 4, 1, 5 also occurs.

The *Hantapara plateau* consists mainly of the two types 2, 4, 3, 5, 1 and 2, 1, 4, 3, 5 with the still lighter 1, 2, 4, 3, 5 type common at Ramjhora.

Lankapara and Gargunda are mainly of the 2, 4, 3, 5, 1 and 2, 1, 4, 3, 5 types.

The following heavier types also occur 4, 3, 2, 5, 1 and 4, 5, 2, 3, 1 also the very light type 1, 2, 3, 4, 5.

The heavier types are probably from Lankapara and the lighter types from Gargunda. The two gardens were sampled before separation.

At Dumchipara the four samples taken are all of the lighter 2, 1, 4, 3, 5 type, which changes into the closely related but still lighter type 1, 2, 4, 3, 5 at Ramjhora, where the 1, 4, 2, 3, 5 type is also found.

At Hantapara the bulk of the garden is of either the 2, 4, 3, 5, 1, or 2, 1, 4, 3, 5 type, the latter lighter type probably predominating. Patches of heavy grey silt of the 4, 5, 3, 2, 1 type also occur. These grey silts are obviously newer deposits overlying the normal soil of the garden, and are probably of the same origin as the infertile deposits already mentioned as occurring in the rest of the district. Those at Hantapara, however, have lost their excess of alkali, and accummulated a good store of organic matter. Although from their physical nature they are not so fertile as the rest of the garden, these heavy silts at Hantapara grow tea very successfully.

SOILS OF THE DAINA TOORSA DISTRICT.

Sandy types.

(Compare these with Mal Sands, to which type only Red Bank Tea Estate and Haldibari approximate closely).

Tea Gardens.	Birpara.	Huldibari.	Ethelbari.	Bundapani.	Red Bank.
Soil type.	2,1,4,3,5.	1,4,3,2,5.	2,1,4,3,5.	3,2,1,5,4.	1,2,3,4,5.
1. Coarse sand ..	20	36	27	13	45
2. Fine sand ...	35	12	39	27	18
3. Silt	13	14	8	42	14
4. Fine Silt ...	19	21	18	6	10
5. Clay	8	10	5	7	3
Organic matter (Loss on ignition) ...	3·5	7·5	2·5	4	9
Soluble humus (Grandeau Organic matter) ...	2·0	3·4	0·8	1·5	4·0
Acidity	1160	1780	625	950	1660

MEDIUM TYPES.

TEA GARDENS.	Choona-bhutti.	Dom Dima.	Bunda-pani.	Banar-hat.	New Dooars.	Telepara.
Soil type.	3,4,1,2,5.	2,4,3,1,5.	2,4,1,3,5.	1,2,4,5,3.	3,1,2,5,4.	1,3,5,2,4.
1. Coarse sand ...	15	13	16	32	22	32
2. Fine sand ...	14	26	32	18	22	13
3. Silt	28	20	15	12	31	24
4. Fine silt	24	23	21	17	3	8
5. Clay	14	12	11	13	14	17
Organic matter (Loss on ignition)	4	6	4	5·5	7·5	4·5
Soluble humus (Grandeau Org-matter) ...	2·1	2·2	1·7	2·7	2·8	1·6
Acidity	2730	1980	1470	2260	1740	1470

HEAVY TYPES.

TEA GARDENS.	Binnaguri.	Gandrapara	Lakhipara.	Demdima.
Soil type.	3,4,5,2,1.	4,5,3,2,1.	4,2,5,1,3.	4,3,2,5,1.
1. Coarse sand ...	8	13	13	5
2. Fine sand ...	9	7	23	19
3. Silt	27	16	11	21
4. Fine silt	26	34	24	31
5. Clay	22	23	18	19
Organic matter (Loss on igntion)	7	8	9	4
Soluble humus (Grandeau Org. matter) ...	...	3·9	3·4	1·3
Acidity	...	1760	3650	1022

SILT–LOAM TYPES.

TEA GARDENS.	Birpara.	Chamurchi.	Dalgaon.	Dalmini.
Soil type.	2,4,3,5,1.	4,3,2,5,1.	3,2,4,1,5.	2,3,4,1,5.
1. Coarse sand ...	10	5	14	10
2. Fine sand ...	35	17	20	38
3. Silt	17	19	32	22
4. Fine silt	22	39	19	17
5. Clay	10	8	11	9
Organic matter (Loss on ignition)	4	9	3	3·5
Soluble humus (Grandeau Org. matter) ...	1·9	3·3	1·3	1·3
Acidity ...	1600	2730	2140	1510

HANTAPARA PLATEAU SOILS.

Tea Gardens.	Average lighter soils of the plateau.						Heavy Soil.	
	Ramjhora.	Dumchipara.	Hantapara.	Gargunda.	Hantapara.	Lankapara.	A heavy clay from Lankapara.	The heavy new deposit at Hantapara.
Soil type.	1,2,4,3,5.	2,1,4,3,5.	2,1,4,3,5.	2,1,4,3,5.	2,4,3,5,1.	2,4,3,1,5.	4,5,2,3,1.	4,5,3,2,1.
1. Coarse sand ...	31	24	23	25	12	9	8	4
2. Fine sand ...	26	27	25	30	24	36	17	7
3. Silt	11	14	15	11	20	21	14	17
4. Fine silt ...	23	17	18	13	23	22	28	44
4. Clay	5·5	11	13	11	15	7	27	21
Organic matter (Loss on ignition)	3·5	6	5·5	4	6	4·5	6	6
Soluble humus. (Grandeau organic matter)	1·6	2·8	2·3	...	...	...	...	1·4
Acidity.	1060	2200	2340	...	...	...	...	1970

INFERTILE ALKALINE SOILS OF DAINA TOORSA DISTRICT.

Soil type.	Loss on ignition.	Grandeau organic matter.	Soluble in dilute acid.	Nitrogen.	Phosphoric Acid.		Available potash.	Available lime.	Available magnesia.
					Total.	Available.			
2,3,4,5,1	4·04	0·84	8·0	·103	·145	·041	·009	·78	·11
2,1,3,4,5	3·0	0·68	5·4	·084	·112	·031	·012	·74	·14
4,3,2,1,5	5·5	0·65	0·63	·106	·116	·029	·007	·221	·016
4,3,2,5,1	5·1	0·55	0·21	·084	·126	·036	·005	.16	·01
1,2,3,4,5[a]	5·7	1·2[a]	4·7	·118	·018	·018	·017	· 8	·34
2,3,4,1,5	4·5	0·48	8·4	·05	·122	·012	·014	·76	·52
2,3,1,4,5	3·4	...	8·5	...	...	...	...	...	...
4,2,5,3,1	4·5	0·49	1·8	·09	·125	·027	·016	·55	·17
4,2,3,5,1	3·2	0·46	0·6	·09	·104	·028	·014	·45	·12
3,2,4,5,1	2·8	0·02	5·9	·07	·20	·032	·014	·65	1·30
3,2,1,4,5	3·2	0·03	1·9	·14	·19	·032	·014	·60	0·34

[a] This soil, although alkaline, grows tea very fairly. Note "Grandeau" organic matter.

The Toorsa-Jainti District.—This is the district where the real grey sandy loam of the Dooars is seen over large areas. The prevailing whitish or light or dark grey colour of the soil generally is very noticeable. It is clearly a comparatively new deposit; frequently deep, overlying white silt or fine sand containing little plant food, occasionally overlying an older rich reddish brown surface soil at a depth within reach of the tea roots. The red-brown soil occasionally still appears as a surface soil. Generally the surface soil is rich but of no great depth; nevertheless the physical character of the soil is generally so good that tea does well, and the district includes some of the finest tea grown.

The characteristic soil types of the district are those referred to under the name "silt loam," when writing of Daina-Toorsa soils. They are soils mainly made up of the three medium fractions, fine sand, silt, and fine silt, and contain little of either coarse sand or clay. Such soils occur on every garden in the district and cover a large area on many of them. Mechanically they are splendid soils for tea Even now although mosquito blight is very distinctly wide-spread in the district, the above soils remain comparatively less attacked than the sands. When the quantity of fine silt is excessive, particularly when clay also is present in significant amount, soils of this nature may be too close-grained to rank as first class tea soils.

Sands (and sometimes very coarse sands) also occur, mainly in patches but sometimes over comparatively large areas. They are chemically very similar to the stiffer soils, but generally have a lesser depth of good surface soil. The sands are very distinctly inferior, as tea soils, to the "silt loams"; and on the sands mosquito blight generally appears first, and does more damage. The mechanical similarity of these sands to the "Mal Sands" is noticeable, but they have not generally the very high acidity and organic matter. The small patch from which the Dima sample was taken, however, bears a very close resemblance to the "Mal Sands."

Clay soils occur only on the gardens just under the hills, Toorsa and Rungamattie. These clay soils, in fact, are on the lowest slopes of the hills, and not on the plains proper.

Subsoils are generally lighter than surface soils, and gravel and stones very commonly appear below the subsoil. When either stones or sand form the lower subsoil splendid natural under-drainage is provided so that "blind" drains frequently appear to be sufficient. Where however the stones appear close to the surface, the growth of tea is not a commercial success, and where these "stony ridges" actually appear on the surface any attempt at planting is a matter of continual infilling, generally attended with disappointment. "Stony ridges," an occasional nuisance in the Daina-Toorsa district, here become a serious problem affecting large areas on many gardens.

No case of infertile alkaline soil has yet been found in this district. This is rather a matter for surprise since these soils are apparently very much what the alkaline deposits may be expected to weather into. Although the soils are of comparatively recent origin, it must be assumed that fresh deposition has now ceased.

The good stiff (but not sticky) types occur as below :

Toorsa ... Average 4, 2, 3, 5, 1 or 2, 4, 3, 5, 1 : less common 4, 3, 5, 2, 1; 4, 5, 3, 2, 1; 3, 5, 4, 2, 1; 2, 4, 5, 3, 1.
Sandier types 3, 2, 1, 4, 5; 2, 4, 5, 3, 1; 1, 4, 1, 3, 5; also occur.

Rungamattie ... The 2, 4, 3, 1, 5 occurs. More commonly heavier types 4, 5, 1, 2, 3; 4, 1, 5, 2, 3; and a light type 2, 1, 4, 3, 5 is fairly common.

Dalsingpara ... Average 4, 3, 2, 5, 1; also 4, 2, 3, 5, 1; 2, 4, 3, 5, 1; 2, 3, 4, 5, 1.
Sandier types 2, 1, 4, 3, 5; 1, 2, 4, 3, 5.

Hasimara ... Average 4, 3, 2, 5, 1; also 4, 2, 3, 5, 1 and 2, 4, 3, 1, 5.
lighter types 4, 1, 2, 3, 5.
a heavier type 4, 3, 5, 2, 1 also occurs.

Chuapara ... 3, 2, 4, 5, 1 and 2, 4, 3, 5, 1.
No analyses of lighter soils available.

Mechpara	...	Only one analysis available 4, 2, 3, 5, 1.
Kalchini	...	3, 4, 2, 5, 1 (only one analysis available, but this was taken as typical of garden). A sandier soil (from Raimatang) is of 1, 4, 3, 5, 2 type.
Dima	...	Average 4, 2, 3, 5, 1; also occurs 4, 3, 2, 5, 1, and one example from a very sandy patch is of 1, 2, 3, 4, 5 type which has the characteristics of the Mal Sands.
Bhatkawa	...	4, 2, 3, 5, 1 and 2, 3, 4, 5, 1. also sandy type 1, 2, 4, 3, 5.
Rajabhat	...	2, 4, 3, 1, 5. Here the sandy type 1, 2, 4, 3, 5 appears to be more common. A sample taken from a sandy ridge is of the 1, 2, 3, 4, 5 type. It contains 95% sand and practically no clay. Naturally, on that spot tea cannot be established.

CHARACTERISTIC SOILS OF THE TOORSA-JAINTA DISTRICT.

SILT-LOAM TYPES.

TEA GARDENS.	Bhatkawa.	Rajabhat.	Chuapara.	Kalchini.	Mechpara.	Hasimara.	Dima.	Dalsingpara.
Soil type.	2,3,4,5,1.	2,4,3,1,5.	3,2,4,5,1.	3,4,2,5,1.	4,2,3,5,1.	4,2,3,5,1.	4,3,2,5,1.	4,3,2,5,1.
1. Coarse sand	1·5	9	2	2	6	2	4	3
2. Fine sand	43	39	29	21	25	21	22	11
3. Silt	26	19	34	40	18	20	26	21
4. Fine silt	19	23	26	24	34	40	30	53
5. Clay	7	3·5	5	9	10	11	10	8
Organic matter (Loss on ignition)	3·5	5·5	4	4	7	5	5	4
Soluble humus (Grandeau or Organic matter)	...	...	...	...	3·3	2·2	...	1·1
Acidity	...	...	...	...	1370	1850	...	950

CHARACTERISTIC SOILS OF THE TOORSA-JAINTA DISTRICT—(*Contd.*)

Tea Gardens.	Sandy types.						Heavy types.	
	Dima.	Bhatkawa.	Dalsingpara.	Rajabhat.	Hasimara.	Raimatang.	Rangamattie.	Toorsa.
Soil type.	1,2,3,4,5.	1,2,3,4,5.	1,2,4,3,5.	1,2,4,3,5.	1,4,2,3,5.	4,1,3,5,2.	4,5,1,2,3.	3,5,4,2,1.
1. Coarse sand	40	39	35	32	22	25·5	17	6
2. Fine sand	31	18	31	28	21	12·5	16	16
3. Silt	15	12	10	12	19	15	13	26
4. Fine Silt	3·5	16	12	16	21·5	26	23	21
5. Clay	3	9	7	7	11	13·5	21	24
Organic matter (Loss on ignition)	7·5	6	4·5	4	5·5	7	8·5	5·5
Soluble humus (Grandeau or Organic matter)	2·6	...	...	1·6	...	...	...	2·4
Acidity	1630	...	...	1380	...	...	...	2180

The Jainti-Sankos District.—This district falls naturally into two areas, comparatively light soils west of the Rydak and generally of a heavier nature east of that river. In both areas soils are chemically rich, and are generally characterised by high organic matter and nitrogen. The Jainti-Sankos soils appear to be older soils than those west of the Jainti; the white and grey colours are replaced by reddish browns. A few patches of dead black heavy soil also occur.

At Jainti in the north occur again patches of alkaline soil on which it has been found impossible to grow tea. In this case, as is usual on such infertile patches, the "Grandeau" organic matter is extremely low, while the matter soluble in dilute acid is high. In the case of these particular patches although the soil type varies considerably, fine silt is always the leading constituent (about 30%) and clay is always present in considerable quantity (about 17%) so that troubles are increased by the impervious nature of the soil, which is particularly marked in the absence of sufficient organic matter.

No analyses of the normal soils of this garden are available.

A little to the south-west at Phaskowa, the sandy type 2, 1, 3, 4, 5 predominates; although a heavy type is also found, the 1, 4, 5, 2, 3.

At Kartik the soils are generally sandy, types so light as the 1, 2, 3, 4, 5 being found, but the 2, 1, 4, 3, 5 is probably more common.

At Dhowlajhora the type 2, 3, 4, 5, 1 predominates. In this type of soil as found at Dhowlajhora the coarse sand and clay each average only 2 or 3 per cent. Although below the average of the district in nitrogen, such soils are physically very well suited for tea.

The sandy type 2, 1, 4, 3, 5 also occurs.

East of the Rydak the soils generally are, or have been, exceptionally rich. They appear very generally to have lain under wet conditions, accumulating fertility, for some time before opening out. A few soils which have been very long under cultiva-

tion now show a comparative deficiency in organic matter which accounts for their lesser fertility, but on the whole the soils are still in splendid condition.

At Rydak the type 2, 4, 1, 3, 5 appears to predominate, but the physical nature of the soil varies greatly from place to place. The uncommon silt types 2, 3, 5, 1, 4 and 3, 2, 5, 1, 4 (previously noted at Rheabari) also occur. Rydak generally is exceptionally rich in "Grandeau" organic matter (soluble humus), and appears to have lain a long time under water-saturated conditions before opening out and draining. The 2, 3, 5 and 3, 2, 5 types are particularly rich in this respect, the "Grandeau" organic matter being between 4 and 5 per cent. in all four samples analysed. Medium sand types such as 2, 1, 4, 3, 5 also occur.

At Newlands the related types 3, 4, 5, 2, 1 and 4, 3, 5, 2, 1 are common. When these types contain a clay fraction of about 20%, they become difficult soils to work unless the organic matter content is very high, as it often is when the soils are newly opened out. Sandier types 2, 3, 4, 5, 1; 2, 1, 4, 3, 5; and 2, 1, 3, 4, 5 also occur.

At Kumargram similar heavy types 4, 5, 3, 2, 1 and related types are found, but the very fine medium types 2, 3, 4, 5, 1 and 2, 4, 3, 5, 1 and a light type 2, 1, 4, 3, 5 occupy large areas.

At Sankos the soils are very similar to those found at Kumargram.

The soils between the Rydak and the Sankos have a general resemblance to those of the Hantapara plateau.

SOILS OF JAINTI-SANKOS DISTRICT.

	Infertile patch from Jainti.	Phaskowa.	Kartik.	Dhowla-jhora.	Rydak.		Newlands.		Kumargram.		Sankos.
Soil type.	4,3,5,2,1.	2,1,3,4,5.	1,2,3,4,5.	2,3,4,5,1.	2,4,1,3,5.	4,3,5,1,4.	4,3,5,2,1.	2,1,3,4,5.	4,5,3,2,1.	2,4,3,5,1.	2,1,4,3,5.
1. Coarse sand	4	36	78	1	18	10	2	19	2	9	24
2. Fine sand	6	40	14	43	33	26	12	47	4	40	29
3. Silt	24	10	5	28	14	34	25	15	21	14	13
4. Fine Silt	43	8	0.5	19	25	15	30	9	35	18	16
5. Clay	16	4	1	2	5	13	21	6	28	12	12
Organic matter (Loss on ignition)	6·5	2·5	2	6	5	11	10	3·5	9	6·5	5
Soluble humus Grandeau (Organic matter)	0·3	0·9	0·8	1·4	2 6	5·1	2·1	1·0	1·7	3·2	2·3
Acidity	Alkaline	900	650	1810	2510	2240	3120	2030	2230	2530	2770

OBSERVATIONS CONCERNING TANNIN IN THE TEA LEAF.

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AND

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Introduction.

In a previous number of this Journal it was shown that the price of Assam teas is based largely on the tannin content of the tea (2). Prices above the average are paid chiefly for flavour, aroma and in some cases for exceptional pungency. North-East Indian teas are generally pungent teas with "body" and the comparatively low prices paid for these qualities is more than counterbalanced by the large crops given in North-East India. The qualities of pungency, "briskness," "body" and thick liquors are all connected more or less closely with tannin products. The "cream" which separates from tea infusion on cooling is also due in part to tannin products.

Finished Indian Teas contain considerably more tannin than Ceylon and China teas as is shown by the table below (1).

	Tannin %			
	Variation.			Average.
Indian Teas	13·32	to	14·98	14·33
Ceylon „	10·31	to	13·91	12 29
China „	7·27	to	10·94	9·50

These percentages are calculated on dry finished black teas and are not comparable with tannin values shown later on. When the

shoot is first plucked it contains from 25 to 30% tannin which, chiefly during the fermentation process in manufacture, is reduced to about 15%. The tannin which disappears goes to make cup colour and "body."

The excess of tannin has been used as an argument against Indian teas in favour of China and Ceylon teas. However, China bushes grown in Assam have about the same tannin content as Burma and Assam bushes. Thus shoots consisting of two leaves and a bud plucked in July showed the following tannin percentages :—

Plucking date.	Tannin % on dry leaf.		
	Burma.	Assam.	China.
July 17th	25·92%	24·20%	24·53%
July 31st	26·57%	24·75%	24·77%

Some years ago an article was published in the *Lancet* showing that the harmful effect of tea tannin was removed when that body was combined with caffeine. It was also shown that in the better quality Indian teas most of the tannin was thus combined. This point has not been further studied but whether most of the tannin is combined with caffeine or not, the compound, caffeine tannate, would be decomposed into its components by the acids of the stomach.

It is highly probable that the percentage of caffeine tannate is influenced by the manufacture of the tea, for the proportion of tannin combined with caffeine is different in fresh leaf and finished tea. Thus in green leaf the ratio of combined tannin to caffeine is about 4 to 1 whilst after manufacture it falls to about 3 to 1 and sometimes less.

Considering that tannin is such an important factor, perhaps the controlling factor, in determining the quality of the teas of North-East India, any study connected with the quality of such teas must necessarily start with the tea tannin.

Below is given some account of preliminary work in this connection.

Experimental Details.

In the experiments described, the tannin was estimated by Lowenthal's method (5). Briefly, this method consists in estimating the matter in solution which is oxidisable by permanganate before and after precipitation by gelatine. The difference is a measure of the tannin bodies. In order to convert this difference into actual weight of tannin, a factor which naturally varies with different tannins, must be used.

A factor was worked out for tea tannin so that the Lowenthal method gave similar results to the tannin as determined gravimetrically by the hide powder method. The factor was found to be 0·0416 grams tea tannin for each c. c. normal permanganate.

In order to study the variation in the tannin content of tea leaf throughout the plucking season the crop from two-half acre blocks of tea from the Tocklai Clearance was used. One block consisted of dark leaved Burma bushes and the other of light leaved Singlo, Assam indigenous, bushes. On each block there were two types of pruning, one half the block being pruned annually and the other half biennially. In the year under consideration (1921) both blocks had been pruned, the annual to 14″ and the biennial to 10″. Both were plucked at 27″, and plucked to the "jhanum" from the commencement of the plucking season.

As soon as the shoots were plucked they were divided into four parts, *viz*:—the bud, the first and second leaf, and the stalk between the first and second leaf. Each portion was boiled for half an hour with water and the filtered liquid was analysed for tannin.

The crop curves for both plots showing the separate yields from the 14″ and 10″ pruned bushes are given in Figures I and II. The total crop for each four weeks is given. The season ended on Nov. 27th so the last point on the curve represents a 3-week crop. By this method of reckoning, the general trend of the crop is shown. The slackening in the upward trend of the crop shown in August is part of the depression extending over four weeks at

this period, details of which are given in an earlier number of this Journal (3).

Apart from the fact that the Burma bushes give a larger crop than the Singlo it is notable that the crop is given earlier. Thus the half season with the Burma 14″ and 10″ pruned bushes comes on August 18th and 25th respectively whilst the half season for the Singlo bushes is August 25th and September 1st respectively.

It is interesting to notice that the crop given by the Singlo bushes for the four weeks ending Nov. 6th is almost double that given by the Burma bushes. The light leaved Singlo bushes were flushing much more vigorously at the end of the season than the dark leaved Burma bushes.

VARIATION IN TANNIN WITH SEASON.

Below are shown the results of the study of the variation in the tannin content of tea leaves. The curves on Figs. III and IV also show the variation.

Tables showing the variation in Tannin content of Tea Shoots during the Season 1921.

Tannin content is shown as percentage on dry leaf.

TABLE I.

Burma Tea pruned to 14″, plucked at 27″

Plucking date.	Bud.	No. 1. Leaf.	No. 2. Leaf.	Stalk.
May 26th	19·88 %	18 02 %	13·70 %	6·28 %
June 9th	19·46 %	23·90 %	19·93 %	10·13 %
,, 23rd	21·52 %	22·21 %	18·44 %	11·47 %
Aug. 4th	19·92 %	21·00 %	18·98 %	11·16 %
,, 18th	25 67 %	26 84 %	23·74 %	10 39 %
Sept. 1st	31·20 %	31·93 %	25·31 %	8·67 %
,, 17th	32·10 %	31·57 %	25·62 %	13·51 %
,, 29th	28·68 %	28 52 %	24·07 %	14·73 %
Oct. 20th	23·89 %	25·65 %	21·78 %	11 87 %
Nov. 3rd	29·13 %	27 74 %	24·72 %	15·54 %
.. 17th	28 89 %	28·65 %	21 63 %	15·73 %
Average ...	25·49 %	26·37 %	21·63 %	12·37 %

Table II.

Burma Tea pruned to 10", plucked at 27"

Plucking date.	Bud.	No. 1 Leaf.	No. 2 Leaf.	Stalk.
June 9th	19·72 %	21·00 %	16·28 %	7·76 %
„ 23rd . ..	21·90 %	20·93 %	17·99 %	10·53 %
Aug. 4th	21·20 %	21·40 %	17·26 %	9·62 %
„ 18th	24·05 %	26·39 %	20·54 %	9·04 %
Sept. 1st	24·10 %	28·57 %	23·97 %	12·31 %
„ 17th	27·10 %	29·90 %	23·67 %	12·48 %
„ 29th	27·51 %	28·91 %	24·15 %	12·32 %
Oct 20th ...	24·96 %	27·88 %	22·86 %	12·40 %
Nov. 3rd	27·48 %	28·56 %	21·38 %	13·17 %
„ 17th	28·33 %	30·28 %	22·80 %	16·54 %
Average ...	24·67 %	26·28 %	21·09 %	11·62 %

Table III.

Singlo Tea pruned to 14", plucked at 27".

Plucking date.	Bud.	No. 1 Leaf.	No. 2 Leaf.	Stalk.
May 26th	17·50 %	16·50 %	13·45 %	5·50 %
June 16th	25·68 %	25·66 %	21·94 %	12·72 %
„ 30th	24·82 %	26·68 %	20·91 %	12·61 %
Aug. 11th	29·36 %	30·15 %	24·54 %	12·92 %
„ 25th	28·94 %	27·33 %	24·09 %	12·88 %
Sept. 8th	27·50 %	28·04 %	21·04 %	12·66 %
„ 22nd	27·61 %	29·46 %	25·92 %	12·68 %
Oct. 6th	28·12 %	30·00 %	26·32 %	11·[illegible] %
„ 27th	23·67 %	24·02 %	22·78 %	11·89 %
Nov. 10th	27·36 %	26·36 %	22·08 %	12·72 %
„ 24th ...	23·93 %	26·17 %	21·00 %	11·94 %
Average ...	25·85 %	20·40 %	22·19 %	11·78 %

TABLE IV.

Singlo Tea pruned to 10", plucked at 27".

Plucking date.	Bud.	No. 1 Leaf.	No. 2 Leaf.	Stalk.
May 12th	16·40%	15·49%	13·48%	7·02%
June 16th	23·47%	24·69%	18·74%	10·98%
" 30th	24·48%	24·75%	20·86%	13·34%
Aug. 11th ...	28·45%	26·69%	20·37%	11·32%
" 25th	26·12%	30·04%	23·24%	10·18%
Sept. 8th ...	24·92%	27·20%	20·70%	11·31%
" 22nd	27·31%	28·05%	23·72%	13·50%
Oct. 6th	27·67%	32·14%	23·14%	9·71%
" 27th	24·49%	24·68%	20·35%	11·47%
Nov. 10th	28·40%	26·83%	22·73%	13·47%
" 24th	25·08%	25·02%	19·32%	12·02%
Average ...	25·16%	25·96%	20·65%	11·32%

Some of the points to be noticed are :—

(*a*) The lighter pruned bushes give more tannin than the lower pruned bushes.

This is of interest in that low pruned tea gives poorer quality tea than high pruned. It must be remembered however that the high pruned bushes were plucked on 13" of new wood whilst the low pruned were plucked on 17" of new wood. Had the low pruned bushes been plucked to 23" the tannin content might have been nearer that of the other bushes.

On the other hand, the quicker rate of growth of the low-pruned bushes might in any case lower the tannin content. It is of interest to note (4) that with fruit trees the slower the growth of the tree the more concentrated the cell sap. Thus, when a tree is lightly pruned, the cell sap is more concentrated. This same argument may apply to the tea bush.

(*b*) The bud and the first leaf constitute the part of the shoot richest in tannin, but the first leaf is distinctly richer than the bud.

Plucking immature leaf may therefore lower the tannin percentage of the fine grades of tea manufactured.

The depressing effect of coarse plucking on quality will be appreciated from the table below showing the average percentage

composition of a fine plucked shoot. The second leaf and stalk, both poor in tannin, comprise well over 60% of the shoot.

Bud	...	... 14%	of shoot plucked.
First leaf	...	... 21%	,, ,,
Second leaf	...	... 38%	,, ,,
Stalk	...	... 27%	,, ,,
		100%	

As more leaves of the shoot are taken, the tannin content still further decreases until the influence of the bud and first leaf is quite overshadowed by the depressing effect of the coarser leaves. Below are given figures which illustrate this.

	Moisture %	Tannin% (on dry leaf)
Bud	76·60	27·94 %
First leaf	78·60	27·94 %
Second leaf	76·80	21·34 %
Third leaf	76·90	17·84 %
Fourth leaf	74·80	14·50 %
Upper stalk ... ... (Bud to second leaf)	86·90	11·70 %
Lower stalk ... ... (2nd to 4th leaf)	84·60	6·43 %

These decreases in tannin with the age of the leaf have been noticed with other plants, *e.g.*, the horse chestnut.

(*c*) The Singlo leaves are, considering individual pluckings, usually richer in tannin than the Burma leaves. This follows the generally accepted idea that light-leaved bushes give better teas than dark-leaved bushes.

The average tannin content of the Burma leaves in Table II is higher than that of the Singlo leaves in Table IV. This is because the Singlo pluckings include one made on May 12th when all the tannin values were low whereas the first analyses on Burma 10″ pruned tea were made on June 9th, after the rise in tannin values which occurs at the beginning of the season.

For the year in which these experiments were made it is noticeable that the tannin content of the Singlo leaves is steady throughout the season whereas for the first part of the season the tannin of the Burma leaves is distinctly low.

(*d*) Seasonal variation.

The low value given by the May shoots is remarkable. The crop in this month is made up partly of the "tipping" which consists, to a certain extent, of slowly grown shoots. The May flush is chiefly made up of shoots which grow quickly as soon as the atmospheric moisture increases as is usual during this month.

In October there is a temporary falling off in tannin. It is impossible at present to explain this. The growing conditions at this period suddenly change, as reference to the Meteorological Chart for 1921 will show (3). Thus the atmosphere has dried suddenly before the temperature has appreciably fallen. In November, although the absolute humidity continues to fall the relative humidity is increasing by virtue of the fall in temperature, and growing conditions are thus again altered.

Only a few such sudden changes in the tannin content of the tea leaf have so far been observed. Thus at the end of June 1922 after the tannin content of the total shoot had risen steadily during the preceding two months from 20% to 30%, there came a sudden drop to 25%. There were no obvious weather changes to account for this, but the rate of growth of the leaf suddenly diminished and the shoots were all about half their usual weight.

The general increase in tannin as the season advances corresponds with the change noticed with regard to other plants rich in tannin, especially the oak and some of the conifers.

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A COMPARISON OF THE VALUES OF FLOUR PHOSPHATES WITH THOSE OF BONE MEAL

BY

H. H. Wiles, M.A.

In Part I of this Journal for 1921 a note was published on the constitution of a sample of Flour Phosphate received by the Department, and the results of a trial of its availability, as compared with that of Bonemeal, upon a six-week crop of cowpeas at Borbhetta.

On analysis the sample proved to be a Calcium Phosphate, giving the following average figures:—

Iron and Alumina	12%
Lime	56%
Magnesia	trace
Total Phosphoric acid	26%
Phosphoric acid, citric acid soluble ...	6%

This crop was grown in the cold-weather (October-November 1920) and received no rain at all with the result that it practically failed, the plants on all the plots making but very little growth and also being attacked by a root disease.

Water-supply being at that season a factor of primary importance, the effects of small dressing of phosphate were naturally only slight, and the results of this first trial may therefore be regarded as almost negligible.

The trial was therefore repeated in the early rains of 1921, after a lapse of six months, but the crop which was sown in the third week in April had to be left in the soil for ten weeks, instead of six, before it could be gathered, owing to the weather throughout May being unfavourable to green crops.

Even then, the crops on the check-plots were barely ready when pulled up, although those on the manured plots, particularly the ones which received the Flour Phosphate, had yellowed somewhat and were obviously over-mature.

Six plots receiving :—	Average crop in lbs. per acre.		Percentage of Check-plot.	
	1920.	1921.	1920.	1921.
No manure (Check)	694·4	1814·4	......	......
Flour Phosphate 40 lbs. P_2O_5 per acre ...	806·4	3852·8	+16	+113
Bone meal " " " " ...	851·2	5353·6	+24	+195
Unmanured strips (3 ft. wide) at sides of each plot	......	1568·0	......	−13

These figures render it obvious that phosphate is here a controlling factor in growth, as both manures show a very distinct effect in spite of the all-round poorness of the crops, due largely to the unfavourable weather conditions already mentioned and also, on the manured plots only, to pre-maturity.

It is noticeable that the Bonemeal in each case gives somewhat the better crop, the Flour Phosphate comparing slightly less favourably with it in 1921 than in the first trial, the ratio of the crop increases produced by the two manures respectively being only 5 to 3 in 1921 instead of 3 to 2 as in 1920.

It is very interesting to note that the effects of the manures are relatively the same on crops grown in the dry and wet weather.

The distinct decrease in fertility, shown by the unmanured drainside strips in comparison with the check-plots, is also of interest, as it is evidently due to "edge effect."

As already recorded for the 1920 sowing, the plots sown with brown imported seed again gave decidedly better crops than those sown with white local seed, although the two varieties were reversed on the plots at the second sowing. This superiority of the brown seed was particularly noticeable where the Flour Phosphate had been applied, the plots sown with it showing an increase of 64% over the white.

Residual Values : In order to test the residual effects of the manures applied in 1920, a further crop of white cowpeas was sown on these plots on May 24th of this year (1922).

Weather was on the whole favourable and the plants made very fair growth on the manured plots, one of the Flour Phosphate plots being quite exceptionally good and giving 60% more crop than the next best plot.

The crops were scarcely mature, however, when they were pulled up and weighed on July 7th, although patches of yellowing plants were very noticeable here and there on the manured plots. The plants on the check-plots would undoubtedly have increased in size if left a little longer in the soil.

In the following table the yields obtained are compared with those of the two previous sowings :—

Manures applied.	Lines of Plants per plot.	Average yields for 6 plots in lbs. per acre.				Percentage Increase or Decrease compared with Check-Plots.		
		1920.	1921.	1922 (Residual).	Total (3 yrs.)	1920.	1921.	1922 (Residual).
Flour Phosphate	5	806·4	3852·8	3158·4	7817·6	+16	+113	+28
Bonemeal ...	5	851·2	5353·6	2643·2	8848·0	+24	+195	+7
Nil (Check-plot)	5	694·4	1814 4	2464·0	4972·8	...	...	...
Nil (Drainside half-plots) ...	4	......	1568·0	1769·6	......	...	−13	−28

It will be observed that, in spite of the distinctly greater initial effect of the Bonemeal up to six months after application, the contrary applies in cases of the residual effects after 18 months, Flour Phosphate having now produced an increase over the checks four times as big as that given by Bonemeal.

At the same time Bonemeal is still quite definitely in front on the total crops for the three years, and it is doubtful whether the residual superiority of the Flour Phosphate is really either as large or as significant as the figures would appear to indicate, as all the manured plots, with the exception of the one Flour Phosphate plot already referred to, gave only slight increases over the check-plots.

The "edge effect" is slightly more marked on the unmanured drainside strips than last year, owing probably to the removal of the two previous crops having to some extent decreased their fertility.

Conclusions: It would therefore appear that Bonemeal contains the higher percentage of rapidly available phosphates, in spite of its less finely divided state.

This may be due to the higher percentage of insoluble phosphates of iron and aluminium in this instance 12%, present in the Flour Phosphate.

The latter, however, seems to be more lasting in its effects, while its physical state makes it easier to apply evenly, and renders more completely and rapidly available such proportion of its phosphate content as may be used by the crop at any time, as is evidenced by the fact that the Flour Phosphate plots were in all cases the first to mature.

A NOTE ON CRICKETS

BY

E. A. Andrews, B.A.

An account of the life-history of the cricket might very well commence at the present time of year (October), for the ceaseless chirruping which is going on just now indicates the fact that the breeding season is in full swing. It also indicates the fact that this is not the best time for the application of poison baits. More will be said of this later.

This chirruping "song" is produced by the male, who sits at the mouth of his burrow with his head towards the entrance, and is presumed to attract the female. Be that as it may, during the day-time they may now be found in couples, male and female, in the burrows.

Occupied burrows may be recognised by the presence of freshly turned up earth around the burrow. This, however, is not invariably present now, but occupied burrows are closed in the day-time by an earthen plug a short way inside, and the presence of this plug is a sure sign of occupation. The female lays her eggs at the bottom of the burrow, embedding them in the soil with an apparatus called the ovipositor, specially adapted for that purpose. They are thus thoroughly well protected.

The eggs are being laid in September and October, and hatch in October and November. After hatching the young crickets live in the parent burrow for two or three days. They then disperse, and each makes a separate burrow for itself, coming out at night to feed. The burrows are short, only 3 to 6 inches down, and may be readily recognised by the small heaps of fresh earth, each with a depression in the centre indicating the mouth of the hole, thrown up on the surface. At this stage the insect makes a fresh burrow each night.

As the insects grow the burrows become longer and cease to be straight, and they may have ramifications. As they grow, also, they are able to tackle larger and larger plants, and thus it comes about that serious damage to nurseries begins to occur about March or April. By July the insects are becoming adult and in this stage they appear to remain in the same hole, or they may occupy empty holes. At any rate they seem not to make new holes for themselves.

The adult does little damage to tea as compared with the younger forms, partly because it has passed the period of growth and is not so voracious, partly because the plants have grown too high, and become too strong to be tackled.

It would be well to begin control measures now by pouring kerosene emulsion, 1 part stock solution to 20 parts water (*see* "Notes on the Spraying of Tea," Indian Tea Association Pamphlet No. 1, 1915, for mode of preparation of kerosene emulsion) into the holes to kill any adult which may not yet have lain eggs. It is hardly feasible to destroy the eggs at the bottom of the burrow, though it might be thought that some solution might be poured in to kill them. This is unfortunately not possible. In order to ensure contact with the eggs the burrow would have to be filled, and since in the majority of cases the burrow turns upwards at the end the eggs are still further protected. Any liquids which kill eggs are exceedingly corrosive, and large quantities of such fluids cannot be poured into soils with impurity, and when the chance of the fluid achieving its object is so small it is certainly not worth while.

The poison bait might come in handy if it could be inserted into the burrows in such a way as to form a plug. The young insects would then, on hatching from the eggs, have to eat their way through it, and would be killed. It would be a big job in a clearance, though it might be done in a nursery, and would demand careful supervision owing to the poisonous nature of the stuff.

It is not worth while broadcasting the bait yet. Such adults as are present are dying out and only a few eggs will yet have hatched, if any. Later on in November and December, when the

small heaps of fresh earth produced by the young crickets are present in large numbers the land should be hoed and then the poison bait spread. The hoe will kill many. The rest will be driven to feed on the bait, since the jungle has been hoed in.

Doing this will probably save much trouble later, and it would not be a bad plan to bait any place, where crickets are active, directly after the hoe.

The poison is made up as follows :—

Husks of rice (*bhusa*), or any green stuff such as chopped up boga medeloa or guinea grass	25 lbs.
Powdered lead arsenate	2 lbs.
(or powdered Copper sulphate)	5 lbs.
(Lead arsenate is better)	
Lemons	6 (finely chopped)
(or 12 drops lemon essence)	
Gur	3 seers.
Water	4 gallons.

Mix the *gur* with the water to form a syrup. Add the lemons or lemon essence and stir well. Then stir the lead arsenate into it. Then pour this mixture on to the *bhusa* or green stuff and mix thoroughly. The bait is then ready for application.

As the bait is poisonous to man and animals, special care is required in applying it.

NOTES ON SOME FUNGUS DISEASES PREVALENT DURING SEASON OF 1922.

A. C. Tunstall, B.Sc.

Root Diseases.

During the present season specimens of root disease have been received in large numbers. At first sight it would seem from this that these diseases are exceptionally prevalent this year. It is however more probable that the condition of the tea market has had more to do with the increase in the number of specimens sent for report than the prevalence of the disease. There is no doubt however that during the war and the subsequent slump planters paid much less attention to the fungus diseases on their gardens and in consequence small outbreaks were allowed to go unchecked. This has in many cases led to very serious damage and in some instances the disease has become so general that the ordinary simple methods of eradication are impracticable. Since the publication of the pamphlets on root disease a considerable amount of further knowledge has been obtained. There is no doubt however that in the case of small outbreaks of root disease the empirical method of digging out all the dead and diseased roots thoroughly is the most practical way of dealing with it, but in th ecases where the disease has been allowed to spread over a large area something further is necessary.

In order to deal successfully with an extensive outbreak it is essential to thoroughly understand the nature of the disease concerned. The treatment which has been found successful in one case will not necessarily serve for another. It is necessary first of all to get a clear idea of the manner in which the various root diseases are disseminated.

Only one disease, *Hymenochaete noxia*, produced no spores on tea. This fungus sporulates on jungle trees but its fructifications are rare. It follows therefore that it must be distributed by

direct contact. As a rule the disease spreads from root to root below ground but it sometimes proceeds along a trench in which woody material has been buried. Quite small portions of diseased tissue are sufficient to distribute the disease and it is essential to remove all the dead wood from the soil surrounding the bushes which have died of this disease. As a general rule the disease originates in the dead roots of a jungle tree. Sometimes the tree has entirely disappeared above ground before the disease makes itself noticeable on the surrounding tea. In our own tea plots at Tocklai this disease occurred in a place which had been grazed over for years. A careful search in the soil, however, revealed portions of a Nahor tree root some feet below the surface. There is only one way to treat this disease, the dead wood must be completely removed as quickly as possible. The disease is specially prevalent on sandy soils. No soil treatment seems to do any good. Unfortunately complete removal takes a lot of time and labour and in the case of large areas the treatment cannot be carried out at once. In such cases the implements used for cultivating the infected areas should be kept separate and operations for the eradication of the disease should be carried out as rapidly as possible round the edges of the patches, the centres being left until labour is available to complete the work. In this manner the disease may be prevented from extending but the bushes still uninfected within the area are not protected. To protect them a trench deep enough to isolate their roots may be dug.

Ustulina zonata spreads from root to root just like *Hymenochaete noxia.* Unfortunately this fungus also spreads above ground by spores. These spores can only attack the plants at decaying wounds such as dead snags on borer holes. As the disease spreads above as well as below ground the treatment suggested for *Hymenochaete noxia* does not apply. When a section is badly attacked the disease is often distributed here and there over a large area and is not confined to one or two large patches. In the case of neglected outbreaks when the fungus has attacked very many plants it is impossible to remove all the plants at once. It is necessary to find some method of rendering the remaining healthy plants temporarily less susceptible to the

disease. As the disease is principally found on acid soils removal of the acidity may help matters. It has been found that heavy dressing of lime have this effect and whenever this disease appears a heavy dressing of lime should be applied to the soil in the neighbourhood of the diseased plants. The dead plants should be removed as soon as possible and all the remaining bushes should be carefully cleaned of all dead snags and the wounds painted with a mixture described below.

Other root diseases resembling *Ustulina zonata* in their effects are occasionally found. One caused by *Kretzschmaria rhizopus* very much resembles *Ustulina zonata* in appearance as well as in its effects. On some deteriorated bheels the tea has become infected with a fungus called *Auricularia Judiae.* This fungus enters the plants at dead snags and after growing through the woody tissue finally attacks the growing layers and kills the plant usually branch by branch. The fungus produces a fruit resembling a brown human ear hence the name Jew's ear fungus. The treatment suggested for *Ustulina zonata* is equally applicable to this fungus.

Sphaerostilbe repens spreads in a similar manner to *Ustulina zonata*, but it is much more susceptible to soil treatment. It is a disease which will only thrive in water-logged acid areas. It has been found that bushes already badly infected will often recover if these conditions are removed. Areas infected by this disease should be heavily limed and the drainage improved as much as possible. All dead plants should of course be removed as soon as convenient.

Rosellinia arcuata. This disease is distributed by spores and by spreading through dead organic matter from bush to bush. It does not readily attack healthy clean stems or roots but generally starts in dead decaying snags or in collections of dead leaves lying in contact with the bushes. It also grows in dead wood buried in trenches. The fungus is particularly susceptible to the action of lime and in most cases the disease can be checked by liming the soil and laying bare the collars of the bushes in the neighbourhood of the diseased ones. Where trenches

have become infected it is necessary to dig out all the infected material. This is a long job and it is suggested that on areas where this disease has been found the trenching material should be sprinkled with lime before being covered up. It is also as well not to make the trenches continuous. In that case if a trench becomes infected comparatively little work will be required to remove all the infected material.

Thyridaria tarda is probably the most widely distributed of all the fungi which may be termed root fungi. This fungus is present throughout the tea districts but fortunately it only does serious damage under exceptional circumstances. The fungus attacks plants through wounds and spreads throughout the wood causing very little damage to healthy, vigorous plants. If however the vitality is lessened for any reason the fungus attacks the layers actively concerned in growth and a moribund condition of the plant results. Plants in this condition succumb to Red Rust, Brown Blight and other diseases. In a few cases the plant dies very suddenly for no apparent reason. This sudden death often occurs after pruning. Bushes which have been moribund for a long time sometimes recover completely when conditions are improved. Drought is one of the commonest conditions rendering plants susceptible to this disease and it is always most prevalent on coarse sandy soils. When tea growing on such soils is cut back or collar pruned this disease often causes much damage. The fungus most readily attacks the cut ends of branches when the wood is drying back. When the soil is deficient in moisture, the cuts do not heal so readily and there is a tendency for them to dry. They are then specially susceptible to this fungus. For this reason it is well to do all heavy pruning very early on such soils and to protect the wounds by a mixture described below. This method has been found very satisfactory on a number of gardens. On most areas of cut back some of the plants do not come away. In many cases their failure is due to *Thyridaria tarda*. It has been found that the application of *2* to *3* ozs. of Nitrate of Potash to the soil round each of these bushes frequently gives them the start. The same treatment applied to moribund bushes is often sucessful but in the case of unpruned

or light pruned bushes in this condition it is desirable, in addition, to spray the plants about April with a fungicide, *e. g.*, Lime sulphur solution to help them to withstand the attacks of Red Rust and Brown Blight which almost invariably attack them severely. In the case of collar pruned bushes which fail to come away the topmost layer should be cut off and the fresh cut painted over, in addition to the Nitrate of Potash manuring. Briefly it is desirable to carry out the pruning when the wounds are likely to be least susceptible to the fungus and further to protect the wounds immediately from the fungus. For the past two years observations have been made at Tocklai of the spores present in the air at varying distances from the nearest tea. It was found that spores of this fungus were less frequently found about September and October although the wind at that time was blowing from the direction of the tea. For this reason also it would seem desirable to prune early. The fungus may also attack the bushes on the roots where the hoe has cut them. This has been noticed in many cases at Borbhetta. To treat the bushes which show signs of the disease by becoming moribund the application of Nitrate of Potash is recommended, aided if necessary by spraying. Dead bushes should be removed as soon as possible as the spores of the fungus are produced in profusion on the dead roots. Although the fungus is always present it is of course desirable to reduce the number of spores available as much as possible.

Dead wood usual source of infection.

From a study of root disease as a whole a few general conclusions may be drawn. With the exception of *Thyridaria tarda*, which is not properly a root disease, these diseases spread principally below ground and any dead wood in the soil is liable to prove a centre of infection. On gardens planted out on Forest land there are generally plenty of tree stumps among the tea and any of these stumps is dangerous. It is quite useless to compile a list of the trees specially liable to start root disease as no woody tree appears to be immune from attack. The burial of woody material in trenches is always likely to lead to trouble unless the wood is sprinkled with lime. This seems to hasten decay and at the same

time prevent the attacks of fungi causing root disease. If a root disease fungus attacks this wood it may be necessary to dig it all out. This is a very expensive operation, but it has had to be done in some cases. Wherever the root disease is prevalent it is wise to break the continuity of the trenches at intervals to limit the extension of any pathogenic fungus which might attack the trenched in material.

When the disease producing fungus is able to spread above ground, dead wood, in the shape of decaying snags, is again the principal consideration and all such should be carefully avoided. Many bheel gardens have bushes covered with snags and if the soil conditions become unfavourable the spread of such a fungus as *Auricularia Judiae* is greatly facilitated. This has been frequently illustrated on deteriorating bheels. The deterioration is in the first place due to soil conditions and the fungi complete the bad work.

Soil conditions. In the case of all root diseases the soil conditions largely determine the susceptibility of the bushes to attack. Most fungus diseases of this nature thrive best on acid soils. The mechanical condition of the soil is of special importance in the case of *Sphaerostilbe repens.* A stiff soil difficult to drain is generally infected with this fungus. It seems that heavy applications of lime tend to make the soil unfavourable to the fungus. The lime besides removing acidity and improving tilth also expedites the decay of dead wood. There is no doubt that much can be done by manuring to render the bushes themselves less susceptible. For instance the action of Potash on the bushes infected with *Thyridaria tarda* on sandy soils. The problem of the influence of soil on the susceptibility of the plants growing thereon to fungus disease or insect attack is a very complex one and further chemical investigation is necessary before definite recommendations can be made.

The danger of delay. Root diseases except *Thyridaria tarda* can be controlled by the simple method of carefully removing the diseased plants immediately the disease is noticed. This method is easily carried out when the outbreak is small, but if small

outbreaks are neglected the disease in question very soon becomes so serious that treatment is very expensive and laborious. In any case sooner or later the dead roots have to be removed and the cost of treatment alone may be very heavy. The loss due to root diseases is enormous and in many cases can be prevented by taking precautions in time. Whenever a plant dies from any cause it should be removed at once. If the cause is unknown the dead plant should be sent to this department with full particulars of the circumstances in which it died. An idea should be given of the severity of the attack. It often happens that a diagnosis cannot be made immediately. If the fungus has produced no fructifications it is often impossible to identify it with certainty and cultures, etc., have to be prepared in order to obtain fructifications. This takes time, perhaps some months. Where the attack shows signs of becoming serious preference may be given to such cases so that further treatment may be delayed as little as possible. No bushes should be regarded as having died from mechanical injury. In all cases disease should be presupposed.

Paint for treating wounds.

A simple and effective fungicidal paint for painting wounds is made as follows. Dissolve 5 lbs. of Copper sulphate in 10 gallons of water and add to this slaked lime in sufficient quantity to make a paste. The use of rice water instead of ordinary water makes the paste adhere better.

Black rot.

During the past few months a number of outbreaks of a serious disease called Black rot have occurred in Assam. This disease is caused by a fungus *Hypochnus theae*. This fungus possesses a very fine mycelium which grows on the outside of the plant like Thread blight. The threads are so minute as to be almost invisible to the naked eye. Even with a lens they are often difficult to distinguish. The fungus attacks the green shoots and leaves. At first it causes a slight discoloration which rapidly becomes darker. When wet the dark patches are almost black, but on drying they resemble those formed by Brown Blight. Sometimes

the patches become infected by Brown and Grey Blight and the true nature of the disease is often masked by this. One of the characteristics of this disease is the manner in which the leaves stick together wherever they touch. It is also noticeable in many cases that the disease occurs in patches on the bushes not like Brown Blight which is scattered all over a bush. The spores are produced on the undersides of the leaves usually on healthy looking green portions. The spore producing area is white, just as though a little dusting powder had been sprinkled on the surface of the wet leaf. The spores are basidiospores and are produced on the ends of hyphæ projecting from the mycelial net. Fortunately in most cases only few patches of spores are to be found and the disease is distributed more by contact than by spores. Coolies working in the infected tea brush off little bits of the mycelium and thus transfer it from bush to bush. When spores are being produced the spread of the disease is much more rapid and infected bushes are found scattered all over a section instead of in patches. The disease is capable of doing very severe damage. On one garden a considerable area of tea has been so severely damaged that a large number of bushes have died right out and the yield of some hundreds of acres considerably reduced. Unfortunately the presence of this disease was not suspected for a long time. The deaths of the bushes had been attributed to root disease and the brown spots on the leaves to Brown Blight. Some years ago a serious outbreak of this disease occurred in a garden in Upper Assam and the writer personally supervised the treatment. This work was reported in the *Quarterly Journal*, Part III, 1918. The results of this treatment were very satisfactory.

Isolation.

When this disease is suspected the area of tea infected should be isolated at once. All the coolies necessary for the cultivation, etc., should be specially selected and not allowed to work in the other tea without being disinfected. The simplest method of carrying this out is to spray the coolies with Lime—sulphur solution as they leave the work. This solution in the strength suitable for spraying tea does not injure the skin or clothing. It

hurts the eyes but it is unnecessary to spray the face. The smell is unpleasant but coolies do not object to it. It may also be pointed out that this solution is a remedy for itch and other skin diseases. The implements, baskets, etc., should also be treated the same way.

Treatment.

The diseased leaves and shoots should be removed and burned. The plants should then be thoroughly sprayed with Lime—sulphur solution. The spraying should be repeated a week or ten days later.

If the disease has spread over a large area, treat all the small patches in the tea showing least infection, including in the treatment three rows of bushes all round the diseased ones. Meanwhile keep the large areas isolated and treat these later as soon as time permits.

As the fungus is wholly outside the plant like Thread Blight it is possible to kill it right out with a spray fluid. A second application is only recommended in case some parts of the bushes have been missed in the first application.

When sending specimens suspected of having Black Rot to the Scientific Department it is advisable to send them packed in a corked bottle as when the specimens are dried up this disease it is very difficult to identify.

NOTES.

"**The Use of Flowers for Infusing**"—The following appears in the International Review of Science, No. 9, Year XII, as an abstract of an article in the *Boletin de Agricultura Industria y Comercio de Guatemala.* Year I, p. 23.

The infusion of the flowers of tea is much less known than the infusion of the leaves, although richer than the latter in aroma and equal to it in all other qualities. In view of the facility for fraud in the leaf-tea trade, the flowers offer several advantages compared with the leaves, *e.g.*, easy plucking, no injury to the bush, much greater difficulty in adulteration.

As the tea bush flowers very abundantly, it would be profitable to work it for its flowers. Tea made from the flowers could be sold at a higher price than that made from the leaves, for not only is it more aromatic but also sweeter and contains less thein. Recently tea made from the flowers, which up to date had been reserved for the exclusive use of the rich people in the principal producing countries, and was not exported, has begun to be imported into Europe.

Tea does well where coffee does well ; its growth in Guatemala, with a view to harvesting the flowers, is therefore recommended.

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THE EFFECT OF MANURES ON THE CONSTITUTION OF THE TEA PLANT

BY

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Introduction.

Within the past two decades the use of manures and artificial fertilizers has steadily increased in the tea gardens of North-East India. The chief object of manuring has been to increase the crop, and the success achieved in this direction can be partly gauged by the fact that the outturn per acre has been almost doubled in the past twenty years. Increased labour force, improved methods of cultivation and treatment have naturally also had a great influence in producing this increase.

While it is now a comparatively simple matter to increase crop by manuring and cultivation, it has happened in many cases that such increase has been obtained at the cost of an increased susceptibility of the plant to blight attack. Susceptibility to blight attack, for example, commonly follows the use of too heavy an application of nitrogenous manure alone.

On the other hand, the plant's susceptibility to disease has often been decreased by correct manuring, generally by the application of potash, lime and phosphates alone or in combination.

In the absence of good drainage, however, results have not been obtained, for it is difficult for manure of any type to exert its influence in a water-logged soil. In connection with water content of the soil and efficiency of manure, Shive (10), dealing with seedlings, has shown that the optimum manurial ratio is about the same, whatever the soil moisture may be, but the crop may be reduced by as much as 50% by making the water content double the optimum.

A study of the acid soils of Assam (2) has shown that the first necessity is generally the alleviation of acidity. An application of lime, potash or phosphatic manures brings about the desired result, but each in a different manner. The type of manure best suited to a soil depends naturally on the physical and chemical state of the soil.

Thus the primary effect for which a manure is added, *viz.*, increased available plant food, is not necessarily obtained in our soils until certain secondary reactions are finished.

Even when the secondary reaction of the manure has been realised, the primary action is not simple and straightforward. Hall (4) fully appreciated this when he proposed to analyse the soil by means of the plant, intimating that ordinary chemical analyses gave no true measure of the plant food in the soil. Some years later, Hall, Brenchley and Underwood (5) showed that there was some relationship between the amount of potash and phosphoric acid in the soil, and of these constituents in certain plants, but it was also shown that the variation between individual plants was often as great as that between plants grown in quite different soils.

Andrews (1), studying the mosquito blight of tea (*Helopeltis theivora*), has shown that if certain of the roots of an attacked bush are put into solutions of potash, the bush is able to throw off the attack in a few days. Solutions of phosphates fail to bring about this phenomenon.

It would thus appear probable that the degree of susceptibility to disease may be correlated with the composition of the leaf produced. Below is an account of experiments undertaken during the years 1918 to 1921, in order to ascertain how far the content of nitrogen, phosphoric acid and potash in the leaf of the tea plant could be altered by ordinary manuring. It is recognised, however, that other factors, such as the water content of the soil and the presence in the soil of substances other than those added as manure, will have a great influence on the plant's content of any particular substance, and therefore no very close correlation between manuring and plant composition can be expected except und er very closely controlled conditions.

The work falls into two divisions, one dealing with sand cultures and the other dealing with fully grown tea bushes.

THE EFFECT OF MANURES ON TEA SEEDLINGS.

In the earlier work on the effect of manures on tea seedlings grown in sand (6), groups containing 10 seedlings were treated with manures varying in their potash, phosphate and nitrogen content. It was shown that the phosphatic content of the seedling varied with that of the manure. The relationship between nitrogen and potash in the plant and that in the manure was shown to be obscure.

The next season (1921) fresh seedlings were grown. Only three different manures were added, and in each experiment there were originally 50 seedlings. By taking this number of seedlings it was anticipated that the effect of individual variability of the plants would be sufficiently diminished to make the average results of value.

Davis (3), studying the effect of different culture solutions on the weight of wheat seedlings, found that even by using 165 plants the arithmetic means gave a very incomplete idea of the value of the different manures. The curves of the frequency of distribution in two cases out of three practically overlapped. Only when the nature of the nutrient solution was entirely changed was any distinct difference in the weight of the crop observed.

Smith and Butler (11), studying the relation of potassium to the growth of plants, drew attention to the fact that potash manures greatly influence the potash content of the plant when potash is the limiting factor.

Accordingly, it was considered possible that, by treating seedlings with manures which were absolutely distinct, a significant change would be observed by analysing about 50 seedlings treated with each type of manure. It was also considered that the chemical constitution of a plant might respond more readily to different manuring than would the total weight of a plant.

The manurial solutions applied to the sand cultures were normal, potassic and phosphatic. The normal manure was based

on the well-balanced manure suggested by Knoop. The nutrient solutions were made from sodium nitrate, potassium chloride, superphosphate, magnesium sulphate and a trace of ferric chloride. Below is shown the constitution of the three solutions :

Manure.	N parts per million.	Water available.	
		Potash %.	Phosphates %
Normal	8·7	·0072	·00077
Potash	3·0	·0168	·00026
Phosphate	3·0	·0024	·00180

With the second and third solutions the potash and phosphate, respectively, are increased to make these constituents the predominating factors.

The seeds germinated in March and in April and were then planted in pure sand. After they were well established the cotyledons were removed preparatory to the addition of nutrient solution. The moisture content of the sand was kept at 15%, this figure having been noticed to give the best results with tea seedlings.

In September the seedlings were uprooted, dried and analysed. By this time only 31 of the 50 seedlings which received the normal manure were alive. Of those receiving the phosphatic manure 38 and of those receiving the potash manure 48 were still alive. The health and freedom from blight of the potash seedlings were marked throughout the experiment. With regard to flushing, the potash seedlings were again superior to the others, both with regard to size of new leaves and earliness of their formation. The seedlings receiving the phosphatic manure were the last to flush.

It may be remarked here that phosphatic manuring appears to improve the quality of tea. It is shown later that the phosphatic content of the leaf of the fully grown tea bush is not appreciably altered by phosphatic manuring ; hence the improved quality is probably due to some other change, and it is quite likely that the slowing up of the rate of flushing observed with seedlings may bring about this improvement.

The analyses of seedlings gave the following results :

Table showing Analysis of Tea Seedlings grown with Different Manurial Solutions.

Manures.	Ash %.	N %.	Phosphates %.		Potash %.	
			In dry leaf.	Ash.	In dry leaf.	Ash.
Normal	7·22	3·11	·503	6·97	1·53	21·20
Potash	7·53	3·25	·479	6·35	1·98	26·32
Phosphate	6·20	3·55	·530	8·40	1·72	27·40

The phosphatic manure increases the phosphate content of the dry leaf considerably but decreases the percentage of ash, whilst the potash manure increases the potassium content of the leaf.

The nitrogen content of the seedling is seen to be much greater in the plants receiving a phosphatic manure than in the others. This effect has been noticed with other plants, especially Leguminosæ (8).

There is considerable variation in the ash content of the different seedlings.

Hence it may be concluded that if potash or phosphates are made the controlling factor in the food of the tea seedling, the proportion of potash or phosphate in the seedling will be increased. This, however, does not hold with shoots plucked from fully grown tea bushes, as is shown below.

The Effect of Manures on the Constitution of the Tea Leaf.

In order to observe the effect of manures on the constitution of shoots from tea bushes, a plot of 252 bushes was selected. The plot was well drained and the soil, a sandy silt, fairly even. Weak bushes were not taken in the experiment. Each manured bush was separated from the next manured bush by three untreated bushes, the middle one of which was taken as the check bush. The lines were lettered A to I, and the bushes in each line numbered 1 to 28. The bushes from lines B, D, F, H were not analysed. The odd numbered bushes in rows A, C, E, G, I were analysed.

The manures were added in April of each year and, reckoning the nitrogen as N, the potash as K_2O and the phosphates as P_2O_5, each bush received manure at the rate of 90 lbs per acre made up in 6 quantities of 15 lbs. each. In the tables at the end the bush number, the amount of manure and the chemical analysis of the leaf are shown.

In 1919 the nitrogen was added as dried blood and in 1920 and 1921 as ammonium sulphate. The potash was added in all three years as chloride. In 1919 the phosphate was added as superphosphate and in 1920 and 1921 as bone meal.

The bushes were plucked weekly and each plucking was dried, and then at the end of each season the total crop was analysed. The yield from different bushes varied greatly and was in some cases almost as much as 2 lbs. green leaf in the season and in a few cases only half as much.

In the analysis of the leaves the phosphate was estimated as ammonium phosphomolybdate and the potash as perchlorate. The values given in the tables refer to percentages in dry leaf, for these figures probably have more significance than the percentage in the ash.

The conclusions drawn from the analyses will now be discussed. First the simple relationships will be considered.

(*a*) *Variation between Bushes.*—The variation shown by different check bushes is as great as that shown by bushes receiving manures of the most varied nature.

The tables below show the maximum and minimum values (excluding one or two exceptional figures which are very wide of the others) shown by different bushes. The values each year do not refer to the same bush.

The first table shows the variation between light pruned bushes and the second between collar pruned bushes. The light pruned bushes were pruned to two fingers of new wood each year and the heavy pruned were collar pruned in 1918, unpruned in 1919, cut to 6 inches above the collar in 1920 and again unpruned in 1921. The collar pruned bushes were plucked at 27 inches

from the ground and the top pruned leaving 6 inches above the pruning cut.

Variation between leaves from light pruned Check Bushes.

Year	Nitrogen %		Potash %		Phosphate %	
	Max.	Min.	Max.	Min.	Max.	Min.
1919	5·39	4·89	2·84	2·03	1·05	0·78
1920	5·98	4·86	2·86	2·09	1·07	0·76
1921	5·79	4·53	2·91	2·04	1 05	0·78

Variation between leaves from collar pruned Check Bushes.

Year	Nitrogen %		Potash %		Phosphate %	
	Max.	Min.	Max.	Min.	Max.	Min.
1919 unpruned ...	5·89	4·72	...	...	...	...
1920 6″ above collar ...	6·25	5·23	2·93	2·40	1·17	0·87
1921 unpruned ...	5·91	4·42	2·98	2·51	1·12	0·88

From this it will be seen that a comparison of actual values shown by differently manured bushes will give information which is always open to doubt. If individual bushes are followed through the three years it is possible to draw some conclusions.

(*b*) *Average Check Bush Values.*—The average shown by the light and collar pruned check bushes are given below :—

Average Analyses of Check Bushes.

	Nitrogen %			Potash %			Phosphate %		
	1919	1920	1921	1919	1920	1921	1919	1920	1923
Light pruned ...	5·05	5 57	5·23	2·63	2·53	2·81	0·90	0·90	0·90
Collar „ ...	5·27	5·82	5·30	2·88	2·64	2·79	0·95	1·01	0·99

The first point noticeable is that the collar pruned bushes give higher figures (except in the case of potash for 1921) than the light pruned bushes in spite of the fact that in 1919 and 1921 they are unpruned.

The nitrogen values rise during 1920 and fall again in 1921. The potash values fall in 1921 and then rise in 1921 to a value higher than that in 1919, so that high nitrogen corresponds with low potash. The phosphate values are fairly steady but show a slight general rise.

Now since cultivation, pruning and plucking have been the same over the three years so far as the light pruned bushes are concerned, the difference in these cases, at any rate, will be largely due to weather conditions. The year 1920 was one of very evenly distributed but light rainfall and this undoubtedly fostered good nitrate accumulation in the soil. This year was a good year for growth of tea. The year 1919 was the driest year of the three, in spite of heavy storms which would tend to minimise nitrate accumulation. Both 1919 and 1921 were poor years so far as the tea crop was concerned.

(c) *Nitrogen Values.*—As a general rule the light pruned manured bushes (irrespective of manure added) were richer in nitrogen than the check bushes during 1919. In 1920 and 1921 they generally dropped behind the check bushes. The values below are the means for the light pruned bushes compared with those of the checks.

Nitrogen Values.

	1919	1920	1921
Check Bushes	5·05	5·57	5·23
Manured Bushes	5·20	5 52	5·21

Thus on the whole the influence bringing about variation in nitrogenous content of the leaves was minimised by manuring.

The only bushes which were generally richer in nitrogen than the checks were those receiving 60 lbs. or more N. per acre. The table below illustrates

Nitrogen Values of Bushes receiving Manures rich in Nitrogen.

Manure lbs. per acre N.—P.—K.	Year. 1919	1920	1921	Remarks.
60— 0—30	5·35	6·23	5·91	Light pruned.
Nil	5·05	5·57	5·23	Check.
60—15—15	5·20	5·96	5·03	Collar pruned.
60—30— 0	5·31	6·05	5·09	„ „
75— 0—15	5·96	6·32	5·31	„ „
75—15— 0	5·91	6·06	6·17	„ „
60—15—15	5·30	5·92	5·66	„ „
Nil	5·27	5·82	5·30	Check.

In these cases nitrogen was evidently becoming a controlling factor in the food supply of the bush.

It is of interest to note that in the third year the influence of nitrogenous manuring is not so marked in some cases as in the first and second years.

(*d*) *Potash Values.*—The factors affecting the potash content of the leaf appear to be very complicated.

The bushes receiving manures rich in potash show no marked increase in that substance in their leaves and are generally poorer in potash than are the check bushes. The mean of the light pruned manured bushes may be compared with the mean of the checks.

Potash Values.

	1919	1920	1921
Check Bushes	2·63	2·53	2·81
Manured Bushes	2·57	2·48	2·79

Thus it is seen that the general variation is in close accordance with that of the check bushes.

During the first year the bushes receiving small doses of nitrogen were generally richer in potash than the checks whilst those receiving large doses of nitrogen were somewhat poorer in potash. During the second year this state of affairs was reversed. In the third year the deficiency was evenly distributed among the manured bushes irrespective of the manure.

The Influence of Nitrogenous Manures on Potash Values.

Manure	1919	1920	1921
15 lbs. N. and less per acre	2·99	2·39	2·82
More than 15 lbs. N ,, ...	2·39	2·58	2·79

(*e*) *Phosphate Values.*—The manures rich in phosphates have no apparent influence on the phosphatic content of the leaf and in many cases this value gradually decreases with time. On the whole the phosphates are steadier than either the potash or nitrogen content of the leaf.

The mean values of the manured bushes may be compared with the checks.

Phosphate Values.

	1919	1920	1921
Check Bushes	0·90	0·90	0·94
Manured Bushes	0·89	0·90	0·95

Thus there appears to be little general change in phosphatic content due to manuring.

(*f*) *Correlation between Constituents of the Tea Leaf.*—That there is a relationship between constituents of the ash of plants has been shown by Leoncini (7) and others. But the relationship is so complicated and the factors at work are so numerous that, before many observations have been made, it is futile to draw very definite conclusions in this direction.

It will be observed that the ratio between any pair of the three constituents, potash phosphate and nitrogen, generally varies in the same manner as shown by the average check bushes. This can be demonstrated by drawing up correlation tables after the manner suggested by Prof. Karl Pearson (9). The three tables shown below are drawn up from the values shown in Table I and Table III, excluding G line, at the end. All these values deal with lightly pruned tea bushes.

The correlation tables are made up as follows. Consider the potash-phosphates relationship. Taking the bush A I in Table I which receives 15 lbs. phosphates and 75 lbs. potash, it is seen that the potash value 2·36 % occurs when the phosphate value is 0·88 %. This relationship will be shown by an unit placed in the second "cell" down in the first column of the potash-phosphate table. The potash and phosphate values occurring in 1921 are expressed by an unit placed in the second "cell" down in the fourth column. And so with all the other values.

In drawing up the tables it was necessary to divide the "population," as the number of examples is termed, into significant classes. It was considered that differences of 0·2 % for potash and 0·1 % for phosphate content of the leaf ash were significant.

In Correlation Table I below is shown the relationship between potash and phosphate values in the leaf. The figures in italics are those corresponding to check bush values obtained from Table III at the end. The second figure is that obtained from the manured bush values, while the third figure is the total.

Correlation Table I.

Showing Correlation between Potash and Phosphate Values in Manured and Unmanured Tea Bushes.

Potash.

Phosphate.		Less than 2·4%	2·4 to 2·6%	2·6 to 2·8%	2·8 to 3%	More than 3%
	0·7 to 0·8% ...	$\left.\begin{matrix}\mathit{1}\\2\end{matrix}\right\}3$	$\left.\begin{matrix}\mathit{2}\\2\end{matrix}\right\}4$	$\left.\begin{matrix}\mathit{3}\\2\end{matrix}\right\}5$	$\left.\begin{matrix}\mathit{1}\\0\end{matrix}\right\}1$	$\left.\begin{matrix}\mathit{0}\\0\end{matrix}\right\}0$
	0·8 to 0·9% ...	$\left.\begin{matrix}\mathit{3}\\8\end{matrix}\right\}11$	$\left.\begin{matrix}\mathit{6}\\4\end{matrix}\right\}10$	$\left.\begin{matrix}\mathit{13}\\8\end{matrix}\right\}21$	$\left.\begin{matrix}\mathit{0}\\3\end{matrix}\right\}3$	$\left.\begin{matrix}\mathit{2}\\4\end{matrix}\right\}6$
	0·9 to 1·0% ...	$\left.\begin{matrix}\mathit{5}\\3\end{matrix}\right\}8$	$\left.\begin{matrix}\mathit{4}\\0\end{matrix}\right\}4$	$\left.\begin{matrix}\mathit{10}\\12\end{matrix}\right\}22$	$\left.\begin{matrix}\mathit{6}\\5\end{matrix}\right\}11$	$\left.\begin{matrix}\mathit{1}\\0\end{matrix}\right\}1$
	More than 1% ...	$\left.\begin{matrix}\mathit{0}\\1\end{matrix}\right\}1$	$\left.\begin{matrix}\mathit{2}\\0\end{matrix}\right\}2$	$\left.\begin{matrix}\mathit{4}\\3\end{matrix}\right\}7$	$\left.\begin{matrix}\mathit{5}\\2\end{matrix}\right\}7$	$\left.\begin{matrix}\mathit{3}\\1\end{matrix}\right\}4$

The total "population" of the table is 131. The number of check or manured bushes separately is insufficient to give any accurate correlation values.

From the table, the mean square contigency is calculated, and from this value the coefficient of contingency may be calculated by means of the formula

$$C_1 = \sqrt{\frac{S}{1+S}}$$

where S = mean square contingency.

The coefficient of correlation, C_2, was also calculated from the mean contingency (9).

The values obtained are as follows :—

Mean square contingency = 0·179, coefficient of contingengy $C_1 = 0·39$.

Mean contingency = 0·157, coefficient of correlation $C_2 = 0·42$.

In considering the correlation between the nitrogen and potash or phosphate content of the leaf the question of significance of nitrogen values presented some difficulty. It was finally decided to take five values differing by 0·25%, varying from 4·75% to 6%, together with a high and low value, making seven values in all. As before, four phosphate values were considered a reliable range.

Below is shown the nitrogen-phosphate correlation table. The separate numbers in each cell have the same significance as in Correlation Table I.

Correlation Table II.

Showing Correlation between Nitrogen and Phosphate Values in Manured and Unmanured Tea Bushes.

Nitrogen.

Phosphate	Below 4·75%	4·75 to 5%	5 to 5·25%	5·25 to 5·50%	5·50 to 5·75%	5·75 to 6%	Over 6%
·7 to 8%	$\left.\begin{matrix}\mathit{1}\\1\end{matrix}\right\}2$	$\left.\begin{matrix}\mathit{2}\\1\end{matrix}\right\}3$	$\left.\begin{matrix}\mathit{0}\\2\end{matrix}\right\}2$	$\left.\begin{matrix}\mathit{3}\\1\end{matrix}\right\}4$	$\left.\begin{matrix}\mathit{0}\\0\end{matrix}\right\}0$	$\left.\begin{matrix}\mathit{0}\\0\end{matrix}\right\}0$	$\left.\begin{matrix}\mathit{0}\\0\end{matrix}\right\}0$
·8 to 9%	$\left.\begin{matrix}\mathit{1}\\2\end{matrix}\right\}3$	$\left.\begin{matrix}\mathit{3}\\3\end{matrix}\right\}6$	$\left.\begin{matrix}\mathit{7}\\4\end{matrix}\right\}11$	$\left.\begin{matrix}\mathit{3}\\9\end{matrix}\right\}12$	$\left.\begin{matrix}\mathit{6}\\4\end{matrix}\right\}10$	$\left.\begin{matrix}\mathit{2}\\1\end{matrix}\right\}3$	$\left.\begin{matrix}\mathit{0}\\2\end{matrix}\right\}2$
·9 to 10%	$\left.\begin{matrix}\mathit{1}\\2\end{matrix}\right\}6$	$\left.\begin{matrix}\mathit{1}\\4\end{matrix}\right\}8$	$\left.\begin{matrix}\mathit{1}\\4\end{matrix}\right\}8$	$\left.\begin{matrix}\mathit{9}\\6\end{matrix}\right\}15$	$\left.\begin{matrix}\mathit{5}\\4\end{matrix}\right\}9$	$\left.\begin{matrix}\mathit{2}\\0\end{matrix}\right\}2$	$\left.\begin{matrix}\mathit{0}\\0\end{matrix}\right\}1$
Over 1%	$\left.\begin{matrix}\mathit{1}\\0\end{matrix}\right\}1$	$\left.\begin{matrix}\mathit{1}\\0\end{matrix}\right\}1$	$\left.\begin{matrix}\mathit{3}\\1\end{matrix}\right\}4$	$\left.\begin{matrix}\mathit{2}\\5\end{matrix}\right\}7$	$\left.\begin{matrix}\mathit{2}\\0\end{matrix}\right\}2$	$\left.\begin{matrix}\mathit{1}\\1\end{matrix}\right\}5$	$\left.\begin{matrix}\mathit{2}\\1\end{matrix}\right\}3$

The mean square contingency, the mean contingency and the corresponding coefficients of contingency and correlation values are shown below:—

Mean square contingency = 0·173, coefficient of contingency = 0·38

Mean contingency = 0·139, coefficient of correlation = 0·40

The Correlation Table of the nitrogen-phosphate values presented many difficulties. The correlation values, as calculated from the mean square contingency and the mean contingency, showed considerable variation. By varying the grouping of the nitrogen and potash, a range of correlation and contingency coefficients was obtained.

The correlation is of the same order as shown by the potash and phosphate values.

Below is shown the Correlation Table for nitrogen and potash.

Correlation Table III.

Showing Correlation between Nitrogen and Potash Values in Manured and Unmanured Tea Bushes.

Nitrogen.

Phosphate.	Below 4·75 %	4·75 to 5 %	5 to 5·25 %	5·25 to 5·50 %	5·50 to 5·75 %	5·75 to 6 %	above 6 %
Below 2·4 %	*2* / 1 } 3	*0* / 1 } 1	*1* / 5 } 6	*2* / 4 } 6	*4* / 3 } 7	*0* / 0 } 0	*0* / 0 } 0
2·4 to 2·6 %	*0* / 1 } 1	*3* / 2 } 5	*3* / 1 } 4	*1* / 0 } 4	*2* / 0 } 2	*2* / 1 } 3	*0* / 0 } 0
2·6 to 2·8 %	*1* / 0 } 4	*1* / 5 } 9	*7* / 5 } 12	*9* / 9 } 18	*3* / 2 } 5	*3* / 0 } 3	*0* / 0 } 2
2·8 to 3 %	*1* / 3 } 4	*1* / 0 } 1	*0* / 2 } 2	*1* / 3 } 4	*3* / 2 } 5	*3* / 3 } 6	*1* / 0 } 1
Above 3 %	*0* / 0 } 0	*2* / 0 } 2	*1* / 2 } 3	*1* / 1 } 2	*1* / 0 } 1	*1* / 0 } 1	*1* / 1 } 2

The mean square contingency = 0·247

Coefficient of contingency = 0·45

Mean contingency = 0·198

Coefficient of correlation = 0·52

The grouping is still unsatisfactory, but it is unjustifiable to arrange the tables so that the variation in the nitrogen or potash values ceases to be significant.

By varying the gradation of nitrogen and potash, the following relationships were obtained. The nitrogen variation was always kept at 0·25% and the potash at 0·2%, the change being made in the magnitude of the upper and lower limits :—

Nitrogen.		Potash.		Coefficient of	
Upper limit.	Lower limit.	Upper limit.	Lower limit.	Contingency.	Correlation.
6%	4·75%	3%	2·4%	0·45	0·52
5·75%	4·75%	3%	2·4%	0·40	0·61
5 75%	4·75%	3%	2·2%	0·47	0·67
6%	4·75%	3%	2·2%	0·51	0·70

The Significance of the Correlation Factor.—The quality of the tea made in any tea garden depends on many factors—environmental, meteorological, personal, etc. It has often been observed that the greater the crop the poorer the quality of the tea produced. Now suppose that every time the crop was doubled the quality was halved, then we could say that quality depended absolutely on the size of the crop. In this case the relationship would be causal. We know, however, that many other factors, beside crop, influence the quality of the tea. Suppose that of the total influences bearing on quality one half were due to the size of the crop, then we should say that the correlation between crop and quality is 0·5. If the crop wholly dominated quality, the correlation would be 1, and in the case of there being no domination at all, correlation would be zero.

If we argue still further we ask the question—why should crop influence quality ? This question can be answered in part. The more vigorous the leaf growth, the less the tannin content of the leaf and the less concentrated the cell sap. Now concentrated sap and a high tannin content make for quality in tea hence it is simply because some of the qualities which are influenced by rapid growth are also connected with good quality in tea that there is a correlation between crop and quality. Correlation in this case suggests parallelism, a case of factors in common.

Reverting now to the correlation between the constituents in the tea leaf we see that about 40% of the influences (correlation 0·42) at work on the potash and phosphatic content are the same. If the potash increases, the chances are 4 to 10 that the phosphates will also increase. The correlation in this case is positive.

With nitrogen and potash or phosphates a similar correlation holds although in this case an increase in nitrogen brings about a decrease in potash or phosphate. The correlation in this case is negative.

Now correlation between plant constituents is only a measure of the relationship between the variation of the constituents. Thus, if the potash values were always 2·5% and the phosphate values always 0·9%, the correlation would be nil. The idea of correlation embodies change. By making the grading of our classes or arrays of constituents coarse enough we can arrange our table so that all the "population" occurs in one "cell." All the table then tells us is that certain constituents invariably occur in the leaf. The relationship in this case is casual.

The importance of correlation between the plant constituents can be appreciated in problems where an attempt is made to increase any particular constituent. Thus it is believed that potash as a manure will be an important factor in the solution of the Tea Mosquito Blight problem.

Although it has been shown that ordinary doses of potash do not appreciably increase the potash content of the leaf it is highly probable that large doses would do so. But at the same time the phosphatic value would be increased. Hence it will be most difficult to influence the ratio of potash to phosphate in the leaf.

Conclusions.

The following conclusions may be drawn :—

(*i*) Heavy pruning increases the nitrogen content of the leaf and tends to increase the potash and phosphate content.

(*ii*) Manures up to 75 lbs. per acre in the case of potash and phosphates have no apparent influence on the potash

and phosphatic content of the leaf. Nitrogenous manures of over 60 lbs. increase the nitrogenous content of the leaf.

In connection with this second point it must be remembered that Tocklai soils are very deficient in nitrogen and hence this constituent may much more easily become the limiting factor than either potash or phosphates. If enough potash or phosphates were added to make either the controlling factor then it is highly probable that these constituents would be influenced.

In considering compound relationship of the constituents of the tea plant, it appears that potash and phosphate vary together, but that nitrogen varies inversely as the other two. Good growth (as in the year 1920) goes with a high nitrogen content and low potash.

Table I

Showing the Variation in Potash, Phosphate and Nitrogen Content in Leaves of Manured Light-pruned Tea Bushes.

Percentage on dry leaf are given.

Bush No.	Manure lbs. per acre N—P—K.			Potash %			Phosphate %			Nitrogen %		
				1919	1920	1921	1919	1920	1921	1919	1920	1921
A 1	0	15	75	3·30	2·36	2·88	0 90	0 88	0·86	5·57	6·14	5·84
A 5	0	30	60	2·71	2·63	2·94	0 85	0·87	0·87	5·13	5·71	5·32
A 9	0	45	45	3·21	2·74	3·22	0·89	0·89	0·81	5·44	6 02	5·43
A 13	0	60	30	2·90	2·64	2·97	0·86	0·94	0·93	4·69	4·78	4 66
A 17	0	75	15	2·73	2·23	2·40	0·85	0·79	0·88	5·33	5·29	4·85
A 21	15	0	75	2·66	2·07	2·68	0·77	0·78	0·80	4·77	5·09	4·91
A 25	15	15	60	3·73	2·50	2·83	0·90	0·78	0 95	5·01	5·98	5·21
C 27	15	30	45	2·79	2·32	2·98	0·88	0·85	0·91	5·70	5·73	4·63
C 23	15	45	30	2·61	2·28	2·66	0·88	0·95	0·99	5 15	4·76	5 30
C 19	15	60	15	2·67	2·29	2·75	1·07	0·85	0·93	5·55	5·38	4·82
C 15	15	75	0	2·61	2·29	2·66	0·97	0·98	1·01	5 27	5·65	5·43
C 11	30	0	60	2·20	2·34	2·79	.....	0·91	0·92	5 21	5·45	5·08
C 7	30	15	45	2·29	2·27	2·73	1·24	0·88	1 00	5·14	4 63	5·46
C 3	30	30	30	2·86	2·38	2·98	.....	0·84	1·00	5·23	5·73	5·60
E 25	30	45	15	2·38	2·62	2·75	0·89	0·99	1·03	5·26	5·22	.....
E 21	30	60	0	1·90	2·45	2·62	0·86	0·88	0 98	5·17	5 11	.....
E 17	45	0	45	2 05	2·66	.....	0·88	0·76	.....	5·04	5·13	4·38
E 13	45	15	30	2·52	2 62	2 81	0 87	0·95	1·00	4·98	6·04	5·85
E 9	45	30	15	2·75	2·62	2·69	0·83	0·93	0·96	5·37	5·30	4·91
E 5	45	45	0	2·49	2·81	2·91	0·60	0·93	1·09	4 66	5·48	5·42
E 1	60	0	30	2·61	3·06	2·85	0·84	0·04	1·05	5·35	6·23	5·91
.....	Average Check.			2·63	2·53	2·81	0 90	0·90	0·94	5·05	5·57	5·23

TABLE II

Showing the Variation in Potash, Phosphate and Nitrogen Content in Leaves of Manured Collar-pruned Tea Bushes.

Percentage on dry leaf are given.

Bush No.	Manure in lbs. per acre N—P—K.			Potash %			Phosphate %			Nitrogen %		
				1919	1920	1921	1919	1920	1921	1919	1920	1921
G 27	60	15	15	2·45	2·68	2 86	0·82	1·01	0·98	5·20	5·96	5·03
G 23	60	30	0	2·54	2·83	2 83	0·84	0·91	1·00	5·31	6·05	5·09
G 19	75	0	15	2·65	2·73	2·58	0·85	0·96	0·93	5·96	6·32	5·31
G 15	75	15	0	3 25	2·75	2·82	1·03	1·09	1·13	5 91	6·06	6·17
I 1	60	15	15	.....	2·77	2·66	..	1·14	1·04	5·30	5·92	5·66
.....	Average Check			2 88	2·64	2·79	0 95	1·01	0 99	5·27	5·82	5·30

TABLE III

Showing the Variation in Potash, Phosphate and Nitrogen Content in Leaves of Unmanured Tea Bushes.

Percentages on dry leaf are given.

Bush No.	Potash %			Phosphate %			Nitrogen %		
	1919	1920	1921	1919	1920	1921	1919	1920	1921
A 3	3 21	2·29	2·64	0·91	0·85	0·78	5 29	5·56	5·40
A 7	3 12	2·53	2·62	0·80	0·79	0·79	4·91	4·97	5·81
A 11	2·48	2·33	...	0·86	0·76	...	5 13	4·68	5·69
A 15	3·07	2·60	2·75	1·00	1·05	0·93	5·25	5·39	5·12
A 19	2 72	2 65	2·43	0 89	0·91	1·02	5·10	5·16	5 03
A 23	2·75	2·56	2·71	0·87	0 88	0·89	4·91	5·73	4 61
A 27	2 65	2·41	2·79	0·83	0·93	0·86	5·39	5·80	5·13
C 1	2·72	2·20	2·75	1·64	0·81	0·97	5·36	5·52	5·79
C 5	2·60	2·09	2·51	0·97	0·87	0·92	4·98	5·58	5·45
C 9	2·14	2·19	2·91	...	0 97	0 93	5·03	5·59	5·06
C 13	2 64	2 68	2·90	0·84	0·88	0·94	5·11	5·98	5·67
C 17	2 67	2·49	2·81	1·00	0·83	0·93	4·89	5·84	5·48
C 21	2·52	2·36	2·74	1·05	0 91	0·89	5·17	5·39	5·11
C 25	2·79	2·30	3 30	0·86	0 95	1·05	5·02	5·35	6·20
E 3	2·58	2 54	...	0·92	0·93	...	4·87	5·74	4·53
E 7	2·84	2·64	3 04	0·98	0·95	1·10	4·85	5·71	4·97
E 11	2·52	2·86	2·68	0·78	1·07	0·91	5 25	5·80	5·27
E 15	...	2·41	2·74	...	0·88	0·99	4·81	5·40	5·36
E 19	2·03	2 75	2·84	0·95	0·83	1·00	4 56	5 57	4·64
E 23	2·09	2·60	2·72	0·94	0·86	1·02	5·19	5·47	5·10
E 27	2·44	2·61	2·65	0·89	0·89	0 91	4 98	5·68	4·58
G 13	2 93	2·93	2·92	0·91	1·06	1·06	5·54	6·11	5 57
G 17	3 45	2·87	2·86	1·31	1·17	1·06	5·89	5·96	5·91
G 21	2·61	2·62	2·74	0·75	0 90	0·94	5·38	5·31	4·42
G 25	2·53	2·93	2·77	0·81	1 09	1·05	5·01	5·74	4·43

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ANALYSES OF TYPICAL TEA SOILS

BY

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While a planter is certainly not expected to make analyses of his soils, it is useful to him to have some idea of the meaning of the figures of analysis when obtained. He will then be able to understand the reasons for treatment advised, and to modify it to suit his own conditions without loss of efficiency.

The accompanying tables show analyses of tea soils chosen as representing the chief types of soil found in North-East India.

The first table shows the sandier soils, which naturally contain relatively high percentages of sand and relatively low percentages of clay. The term "sandy" can of course only be used relatively. The first two would be better called sandy loams. These two are of much the same physical composition (as can be seen from the mechanical analyses) and are physically excellent soils for tea, being mainly sand with sufficient clay to bind them nicely and give that "crumb" in the soil which signifies good tilth.

No. 1 is an old teelah which has been badly washed although now fairly well protected by bunds. No. 2 is an unusally rich virgin soil from the same neighbourhood. Originally they must have been the same chemically as well as physically. Note now the differences between the two chemical analyses, particularly in "loss on ignition" (total organic matter), "Grandeau organic matter" (soluble humus) and in nitrogen. It is in consequence of these differences that No. 1, for many years under normal Cachar pre-slump plucking, gave only about five mds. pucca tea per acre. This was certainly cheaply produced, but had the soil maintained in the condition of No. 2 it would be giving 15 mds. of similar tea.

Having reached its present low condition of fertility, No. 1 soil will probably not drop further very rapidly, but white ants are doing serious damage to the poor bushes, and a certain number of bushes die out annually from Thyradaria tarda, a fungus disease of the stem usually serious only on weak plants.

Money is being wasted on cultivating vacancies and non-yielding bushes, while the smallness of the crop increases plucking and manufacturing cost per lb.

In these days of shortage, is the labour being used to most advantage? Mechanically it is a beautiful soil. Money wisely spent on infilling and manuring would certainly yield a big return.

What manure does the soil want? The selection is easy when we can compare with a good soil mechanically similar and in the same district.

The acidity is too high, and the phosphoric acid not as high as it should be. We must add a little lime and phosphoric acid, particularly as it is absolutely essential that we shall grow good green crops.

Potash is probably high enough. It would be well to run an experiment to see what potash manuring would do, but on the analyses we should judge potash manuring to be not essential and so will save expenditure on that item.

Above all we want organic matter and will add it in every way that the local conditions make possible, taking into account distance from lines and jungle.

Any cattle manure available will of course go on. Green jungle may be near enough to cut and carry on. Generally, however, we have to rely on green manuring and will do as much as we have labour to manage.

Prunings of course will never be burnt but always hoed in, except heavy prunings which are dangerous where there are root diseases.

With our organic matter we have added a lot of nitrogen, but as we have not unlimited labour we must supplement it by

artificials. This soil has so much sand that it can decompose the less readily available manures (particularly when lime has been added) and it contains enough clay to carry the most readily available. We can choose annually the cheapest form of nitrogen which is known to be efficient.

No. 3 is a real sand, one of the coarsest in tea.

Under Bishnauth rainfall it does splendidly under tea. This particular soil has done so for many years, but is now showing signs of deterioration.

On a sandy soil the bushes have a large root range and explore an enormous volume of soil for food. What food there is, too, is in a more available condition than on a heavier soil. Water does not lie on such soils, and with a few deep drains to keep down the rains water-level these sands do well, because the soil aeration is automatically good.

Sands, however, make such good use of added manure that it is always a pity not to manure them ; and in this particular case the soil is getting a bit deficient in some respects. Notice particularly the potash. Nitrogen and organic matter are pretty good for such a light soil but should be at least maintained.

The main trouble with such soils is not their chemical but their physical properties.

Water moves very rapidly through a sand, but will only lift water by capillarity for a comparatively short distance. As the surface dries so more water comes up rapidly from below to be evaporated away, while a sand cannot draw on the stores of water in the deep subsoil. In consequence the water content of a sand is very seriously reduced during a drought. In 1919 much tea on similar soils died right out, while much of what remained alive was so weakened that it was very seriously attacked by blights, brown blight, red rust, *Thyradaria tarda.*

This year's early dry period again did damage.

A coarse sand is a splendid soil where the cold weather water-level is comparatively high, and the rains water-level

comparatively low. The rains water-level must be low in order to get roots down near the soil which will remain moist in the dry season.

A position near a river bank, where the water remained about 8 feet from the surface, would be ideal. Where such is not the case, every effort must be made to conserve the water in the soil during the dry season, by keeping the surface clean of jungle (which pumps out water) and by keeping a loose surface mulch to hinder evaporation.

In the Jorhat district the water-level is commonly pretty high, and the typical soil is, like No. 5, mainly made up of fine sand with little coarse sand. Such soils, while coarse enough to permit rapid percolation of water (hence good aeration), are fine enough to be able to lift water from a much greater distance than No. 3 can. Even No. 4, which is representative of the Jorhat coarser soil, is still fairly good in this respect.

No. 5 represents the geologically older soil of the district, while No. 4 is probably a newer deposit.

The newer deposit contains much more lime (hence the low acidity) and more phosphoric acid. The newest deposits near the Dessoie River are occasionally actually alkaline to litmus and very rich in lime. The newer deposits are distinguished by a very low content of organic matter. They have not been long enough in position to collect a good supply of organic matter from jungle residues in the surface soil, and are therefore particularly infertile. Tea does not flourish in a soil too rich in lime, neither does it do well in soils too deficient in organic matter. In consequence new alkaline deposits, when planted, are frequently afterwards abandoned, although jungle (particularly leguminous jungle) grows well. There are many such cases in the Dooars. There are cases where tea does quite well in alkaline soils if only the organic matter is sufficiently high, but on the whole a soil which turns red litmus blue is better avoided for tea. No soil could retain much lime under our rainfall for long, and an alkaline soil is either very new, very impervious to water, or both.

No. 4, although for all practical purposes neutral to litmus, now does very well, but it required several years of addition of organic matter to change it from a distinctly poor soil. The particular test* which measured this soil's lime requirement at 245 parts per million is one which exaggerates enormously the amount which should actually be applied. The acidity figures are only of value in a comparative sense, and would have no value at all but for one's experience of results on other soils, of which we have analyses.

No. 4 certainly wants no more lime, but No. 5 has too high an acidity for such a light soil, and one would guess it to need some lime. It has, in fact, shown good results from liming.

Being sandy, No. 4 is rich enough to do fairly well without manuring in this district; but will certainly give results from additions of nitrogen, phosphoric acid and a little potash too, and can do with all the organic matter it can get. On No. 5 the crop was being very seriously limited by its need for phosphoric acid until some was added. Otherwise it is quite well off, but still gives value for additional nitrogen, organic matter, and a little potash.

On a sandy soil it is a safe rule to add potash, unless it is pretty certain that it is not needed. Even if little additional crop is obtained in the first year, it helps to keep the bush in better condition.

No. 6, although it contains no more clay than No. 1, is mainly composed of silt, and not sand. Silt behaves like a very fine sand, but when containing a significant quantity of clay and very little sand as No. 6 does, silt soils are most unpleasant to work, unless well provided with organic matter. They pack down tightly so that they are very little aerated, and they behave like solid stone in dry weather. They are generally on the poor side chemically. That is easy to remedy, but it is not easy to remedy the defects of their mechanical composition.

In the case of No. 6 lime will assist, because it will help to flocculate the clay which is present. In many soils of much the

* Albert method as modified by Lyon & Brizzel.

same nature, which contain little clay but much fine silt, we cannot hope for much from lime. But in all such cases our main hope lies in getting in organic matter, and it must be got in deeply. We must trench in and deep hoe in all the green stuff and cattle manure, and prunings that can be obtained.

Drainage, of course, must be close and deep. On account of the close packing of the soil particles, the soil space is already too small. We cannot afford to let any of it be occupied by excess water to the exclusion of air.

Even with as much work as is normally possible on such soils they seem to get hardly any better for years: but after, say, four or five years a manager does admit that his particular bad section is looking a bit better and giving a bit of leaf. Improvement then becomes more rapid if the treatment is maintained.

No. 7 is an example of the rich, dark-coloured sand common in the Dooars.

It is even more coarsely-sandy than the Bishnauth sample, yet is much richer than the average, very-much-heavier soil. It compares well with the remarkably rich virgin soil from Cachar (No. 2).

Yet No. 7 is among the oldest of the Dooars gardens, and the patches of the same soil (which covers a large area) that have not been so long under tea are even richer.

These sands are apparently enriched by old surface soils washed down from the Darjeeling hills.

Looking at the figures for No. 7 one sees that it is well off in every respect, except that it is rather low in potash and is for such a light soil excessively acid. Such a soil has given good results from potash, and, judging by planters' reports, lime also benefits sands of this character.

The curious thing is that they also give good results from nitrogen, although from analyses one would judge them to have ample. Apparently, the nitrogen is present in forms only slowly available to plants. Further experiments may show that the final result from too much nitrogen is to weaken the bush and lay it

more open to blight attack, but soils of this type which have received light dressings of oilcake for years now certainly look much better than more neglected soils, and give good yields of good quality tea. These soils have always been bad for mosquito blight, but are now becoming relatively better.

Treatment of the soil for mosquito blight has only just reached the experimental stage, but we have a fine lot of experiments being very well run, particularly in the Dooors, and we shall know something about the subject when these experiments have run for some years. So far one can only say that a certain amount of success has often followed the use of potash and lime, and that anything which weakens the bush increases the bad effect of any blight. On sands weakness following drought is a reason for increased loss from mosquito. Present-day drainage and cultivation would certainly tend to improvement in this direction, and the relative improvement of these sands possibly may be correlated with improvement in work.

Clay Soils.

As a contrast to the sands just examined, take the figures for the clay soils on Table III.

Here you will notice that the mechanical analyses show very little sand but large percentages of fine silt and clay. The examples have all been chosen from the same neighbourhood, because, when the climate is the same for each, the influence of the soil is more directly seen on the crop obtained.

No. 16 is the stiffest soil of which we have record. When dry, a pickaxe could hardly cultivate it ; when wet, it is like glue. Had this soil been deep, it is probable that it could not have been kept in cultivation. Yet it is, compared to the sands, very rich chemically, even in respect of organic matter, the most active agent in improving a clay. When first planted, the young tea certainly grew but very slowly even in the virgin soil, and took several years to get through one foot of this clay into the subsoil of pure rich peat. Then the tea went ahead.

The clay is rich and would be worth carrying on to a sandy soil as manure, yet is so heavy that, but for its peat subsoil, it would probably prove a very poor soil for tea.

It is clear, then, that the figures given by chemical analysis are of no use except when considered together with the mechanical analysis.

Although rich this particular clay is a bad soil, simply because so impervious to water and air.

No. 2 is physically much less clayey, but is still quite heavy enough to be a real bad soil when the organic matter content is low.

"Loss on ignition" measures not only the combustible organic matter in a soil but also the water driven off from soil minerals by heat.

The "Grandeau" organic matter is a safer guide to the amount of useful organic matter in a soil.

Note the "Grandeau" figure in No. 17. It would be low for a sand, and for a clay it is altogether inadequate.

The nitrogen at ·116% would be good enough for a sand, but indicates a very poor clay. Phosphoric acid and potash are on the low side and need increasing, but the chief need of this soil is a better physical condition. It would be better if it had more coarse sand, but one could not, of course, afford to carry on enough sand to make any difference. To increase the sand by 1% in the top foot would require about 20 tons of sand per acre. The burial of broken earthenware pots such as Howard advises for Bihar indigo soils would certainly be beneficial, but again the cost of such treatment would be prohibitive.

Villagers often do make a big improvement in such soils by scraping into heaps with rubbish, and burning the heaps when dry. The heating of the soil and the formation of lumps of red burnt ballast both greatly benefit the soil's physical condition. Such treatment might be actually carried out on tea land before planting, but is of course impossible on planted land.

In practice, we are limited to the use of lime and organic matter. The use of lime is always to be advised on a clay (even if the acidity of the soil is considered to be doing no harm), because it flocculates the clay and so increases the soil space and allows freer percolation of the soil by water and air.

Organic matter acts in much the same way, and even a little makes a difference.

This soil then could be considerably improved by a course of treatment including lime, green crops (with phosphates) and added nitrogen. Potash is probably not required. With a clay one follows the rule that potash is not applied unless there is evidence of its need. Exception to this rule may be made in the case of cut-back tea.

With all heavy soils it is absolutely essential that drainage must be thoroughly efficient. Without that, no treatment can have much effect.

Nos. 18 and 19, in spite of their high percentages of fine silt and clay, grow beautiful tea. Note their high contents of organic matter.

No. 18 would, no doubt, benefit from phosphatic manure, and the organic matter content of both needs maintaining by occasional green manuring.

Otherwise they should require nothing for many years, although lime would probably do good, and should, at any rate, be tried experimentally.

No. 18 is a teelah soil. No. 19 is a drained bheel, but on account of its high percentage of clay we shall not expect it to suffer the deterioration which has set in on the true peats and peaty sands of the district.

Bheel Soils or "Humus" Soils.

When the amount of organic matter in a soil is very high its influence on the texture of the soil is so great as to make almost negligible the effect of whatever sand, clay, etc., may be present.

The organic matter in No. 19 is high, so high that a soil which with normal organic matter would be a poor one is actually one of the very finest tea soils in India.

No. 19 is a bheel soil in the sense that it is a flat formed by draining a shallow lake, so also are 16 and 17.

No. 16 is peat-bheel in the subsoil, but the peat first accumulated in it has been covered by a later deposit of clay.

No. 20 is an example of a real peat, a little mixed with soil on the surface and becoming pure peat underneath. Note the extraordinary richness of it. Many samples of cattle manure are not so rich.

The peats in this country are not preserved moss as they are in Britain, but at our higher temperatures decompose to a large extent into useful plant-feeding humus. Newly planted peat bheels yield enormous crops. Unfortunately they do not last.

No. 21 is still described by the Manager as a peat soil. It is probable that it once was so, and there is still real peat at only one or two feet below the surface.

The analysis of the present surface soil is that of a very rich sand. It resembles in many respects a garden soil that has for years been overmanured with stable manure. It does not "bind" at all. In the dry season a light cane can be pushed right through, without effort, up to the handle.

This soil has lost its sticky colloidal fine particles, and is of such a loose open texture that its water-lifting power is very limited. One sees such soils dust-dry at 1 ft. from the surface when water is running at the bottom of 3 ft. drains. Roots never penetrate far into a peat, and in consequence the tea on a deteriorated bheel is left high and dry in the cold weather, although possibly only a few feet above water.

The mosquito and other blights on No. 21 take most of the crop.

True peats deteriorate in very similar fashion.

Note the "coarse sand" in No. 20. Seven per cent. of this soil remained on the sieve used to separate out coarse sand. When this "coarse sand" was burnt nothing but a very light ash remained. It was not coarse sand but large particles of vegetable matter.

In deteriorated peats the "colloidal" organic matter has largely disappeared, leaving particles of organic matter of comparatively large size, and they can no more lift and hold water than the humus sands like No. 12.

Water commonly runs through bheels in the cold weather. A lot can be done by keeping up the level of the water in the drains to 24″ or even 18″ inches from the surface by a series of weirs. This is because "film water"—water lifted by capillarity—is not sufficient for the needs of a plant on these curious soils, which not only cannot retain water but also need a lot.

Note the water content of No. 2. 62 per cent. of the stuff in the sample box was water, but the sample was not unduly wet.

A soil which is normally mainly water naturally contracts as it dries and when to this loss is added the organic matter washed away and oxidized away it can readily be appreciated how rapidly such soils may sink under the influence of drainage and cultivation.

Many still good peats are out of cultivation merely because they have fallen below the level of the drainage outfall. A peat requires shallow, close drainage, and the water level must be kept up in the cold weather.

The theories on other possible treatments of peats are fascinating, but there is no space to deal with that about which nothing definite is known. One garden only is experimenting in this direction. We shall welcome offers to undertake further experiments.

Medium Soils.

The special properties of the sands, clays, and humus soils having been examined; those of the medium soils may be

fairly well guessed at, since they may be regarded as mixtures of sand, clay, and humus in various proportions.

No. 8 differs only from Nos. 1 and 2 in having a little more clay.

No. 9 being evenly graded, that is containing a fair quantity of particles of all sizes, will tend to pack tightly and set hard. It is quite well off in organic matter which keeps it good and is otherwise rich except that it certainly needs more phosphoric acid.

No. 10 is very similar, but not so good a soil. It has been much longer under tea. Organic matter is rather low for the type of soil, and added nitrogen will certainly give better crops.

No. 11 would be decidedly heavy and sticky were it not for its content of organic matter. It is practically a virgin soil on which the young tea is now splendid, though it at first hung fire when the drainage was deficient. The nitrogen is distinctly low; at present in the virgin soil what is present is in a very available state, but additions of nitrogen will soon be required.

A soil with so much clay and of so high an acidity must benefit from lime. So, probably, would Nos. 8, 9 and 10, but experiments should first be tried.

All these are heavy enough to need really good drainage. No. 12 is a medium soil, not because it contains both clay and sand but because it consists of the medium-sized particles only. This is the very finest physical type for a tea soil. Having little coarse sand, water movements are not too rapid, and having little clay they are never too slow. Hence it is a splendid soil in spite of its low content of organic matter. Chemically it is rich in minerals but rather low in nitrogen. Having neither clay nor high acidity lime is not likely to be required. These soils generally overlie coarse sand or gravel subsoils and blind drains leading the water into the pervious subsoil are generally sufficient, so long as these subsoils are occasionally tapped by deep drains, and the garden protected from outside water.

Similar to these Eastern Dooars soils are the characteristic soils of Mangaldai.

From their analyses the red bank soils, Nos. 13, 14 and 15, would be expected to behave as rather sticky clays in spite of their high sand content. These red soils, however, always behave as much lighter soils than the quantity of clay present would lead one to expect.

The clay particles measured by mechanical analysis are all those below ·002 mm. in diameter. In a red bank soil, however, the particles of clay size include a much smaller proportion of the very small sticky colloidal particles which give to true clay its peculiar properties.

All these are fine soils. No. 13 grows the oldest and worst, No. 14 the best tea on the same garden. Allowing for the fact that No. 14 is the lighter there is little to choose between the two soils. No. 13 carries distinctly poor tea for red bank soil. No. 14 gave 24 mds. per acre unpruned in 1915.

I believe that the difference is due only to the excellence of the plants and the way they were put into No. 14. This is only mentioned to show that the soil is not everything. The plant is of at least equal importance.

Although the red soils always do behave as lighter soils than would be expected, the average Dooars Red Bank soil does contain a very high percentage of fine particles, and is therefore largely dependent for its excellence on a high content of organic matter.

Note the high organic matter content of No. 15 which has not been long under tea.

There is every reason to suppose that most red bank soils approached these figures for organic matter when first put out, and it is my opinion that it is high time that strenuous measures should be taken to maintain and increase the organic matter content of the older soils.

The common practice of burning prunings year after year can only be deplored. If burnt at once, while green, something might be said for the practice as an anti-blight measure. Generally, however, purnings are left to dry before burning, by which time thay have done nearly all the damage they can.

It is a significant fact that the subsoils of some red bank soils are richer in organic matter than the surface soils. This can only indicate deterioration of the surface soil.

Decreasing organic matter may be one of the factors allowing increased damage from mosquito blight. Mosquito has been very serious of late years even on the fine tea of No. 14. No. 15 remains practically free. Note also the high available potash of No. 15.

TABLE I.

SANDY SOILS.

	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7
	Cachar Sandy Teelah.		Bishnauth Sand.	Jorehaut Soils.			Mal Sand (Dooars)
	Old	Virgin		Newer Deposit	Older Deposit	Silty type	
SOIL TYPE.	2·1·5·4·3	2·1·5·4·3	1·2·3·5·4	2·1·3·4·5	2·3·4·5·1	3·2·5·4·1	1·2·4·3·5
Moisture as received	2·4	8·1	9·1	10·7	1·0	....	15
Hygroscopic moisture	2·1	0·5	0·7	0·4	0·8	0·9	1·4
Gravel and Stones	2·9	0·2	0·5	Nil	Nil	Nil	8·0
MECHANICAL ANALYSES.							
Matter soluble in dilute acid	0·9	0·4	0·2	·02	0·7	0·5	0·3
Coarse sand	31	32	56	22	5	2	64
Fine sand	34	36	24	49	55	18	16
Silt	7	6	11	17	18	56	4
Fine silt	10	9	2	6	11	9	7
Clay	12	11	3	5	6	12	4
Loss on ignition	4·4	5·6	3·2	1·9	2·9	2·4	4·8
CHEMICAL ANALYSES.							
Grandeau organic matter	1·0	2·4	1·3	0·7	1·4	0·8	2·4
Acidity	1716	1190	922	245	1168	974	2633
Insoluble silicious matter	91	92	90	95	93	91	85
Nitrogen	·071	·155	·078	·061	·065	·067	·124
Total phosphoric acid	·015	·034	·057	·058	·019	·034	·081
Available " "	·011	·016	·011	·007	·001	·008	·019
Available potash	·020	·013	·005	·012	·013	·011	·009
Available lime	·012	·057	·038	·057	·016	·021	·017
Available magnesia	·007	·040	·049	·015	·018	·018	·022

Table II.

MEDIUM SOILS LOOSELY TERMED LOAMS.

	8	9	10	11	12	13	14	15
	Sylhet Teelah.	Cachar Plateau.	Dibrugarh Medium Loam.	Central Dooars Clay-Loam.	Eastern Dooars Silt-Loam.	Red Bank Soil.		
Soil Type.	1·2·5·4·3	3·2·5·1·4	2·5·1·4·3	4·5·3 2·1	2·3·4·5·1	1·5·4·2·3	5·1·4·3·2	5·1·3·4·2
Moisture as received	15	21	15	17	20	17	18	27
Hygroscopic moisture	1·2	1·8	2·4	2·1	0·7	2·6	3·0	7·3
Gravel and stones	Nil	1·0	nil	1·4	0·2	1·4	1·8	4·3
Matter soluble in dilute acid	·4	·4	·2	2·5	·6	1·3	1·7	1·2
MECHANICAL ANALYSES.								
Coarse sand	39	15	16	10	5	25	19	22
Fine sand	23	26	34	12	31	14	10	6
Silt	8	25	12	13	29	11	12	17
Fine silt	11	12	15	32	25	18	18	14
Clay	14	16	17	21	6	23	33	31
Loss on ignition	4·7	6·4	5·9	8·8	3·5	7·1	7·8	9·8
CHEMICAL ANALYSES.								
Grandeau organic matter	1·9	2·1	1·8	4·0	1·4	2·1	2·8	4·3
Insoluble silicious matter	87	80	79	74	82	71	68	67
Acidity	1246	2264	1951	1464	853	2875	3671	3264
Nitrogen	·141	·125	·100	·079	·089	·120	·113	·220
Total phosphoric acid	·037	·051	·087	·219	·157	·082	·152	·099
Available phosphoric acid	·011	·006	·015	·043	·060	·012	·014	·016
Total potash	.....	·393	.....	·73	.....	·85	·87	.....
Avaliable potash	·011	·011	·015	·024	·017	·016	·018	·024
Total lime	.....	·092	.....	·130	.....	·131	·094	.....
Available lime	·027	0 31	·016	·033	·145	·054	·028	·030
Total magnesia	.....	·600	.....	·73	.....	1·45	1·09	.....
Available magnesia	·009	·050	·013	·065	·112	·050	·06	·033

Table III.

CLAY SOILS.

	All from Hailakandy District of Cachar.				Bheel Soils Cachar.	
	16	17	18	19	20	21
Average yield maunds with coarse plucking	...	6	14	30	Good peat bheel.	Deteriorating bheel.
Soil Type.	5·4·3·2·1	4·5·3·2·1	5·4·2·3·2	4·5·3·2·1		
Moisture as received	29	26	24	19	62	10
Hygroscopic moisture	·5	2·0	10·9	3·1	10·4	2·7
Gravel and Stones	Nil	Nil	nil	Nil	Nil	Nil
MECHANICAL ANALYSES.						
Matter soluble in dilute acid	·48	·71	1·97	2·36	2·5	1·2
Coarse sand	Nil	0·3	·02	0·4	Nil	35
Find sand	2	9	17	4	7·0	33
Silt	7	18	16	10	7	8
Fine silt	41	35	27	39	26	10
Clay	43	29	28	31	11	3
Loss on ignition	5·6	6·4	8·4	12·6	33	7·3
CHEMICAL ANALYSES.						
Grandeau organic matter	2·8	0·8	3·7	4·7	20·4	3·3
Acidity	2381	1733	3215	2984	5251	1841
Insoluble silicious matter....	73	79	75	74	55	87
Nitrogen	·236	·116	·200	·213	·574	·123
Total phosphoric acid	·088	·026	·068	·114	·194	·065
Available „	·022	·014	·005	·025	·053	·014
Total potash	.....	·23	....	·64	.....	.....
Available potash	·010	·011	·014	·013	·036	·025
Total lime	.....	·19	.....	·94	.....	.....
Available lime	·057	·094	·083	·127	·024	·022
Total magnesia	.....	·28	.....	·23	.....	.....
Available magnesia	·057	·079	·041	·026	·030	·010

A FEW NOTES ON DISEASE TREATMENT

BY

A. C. TUNSTALL, B.SC.

There are a number of diseases of tea, *e.g.*, Grey blight, Brown blight, commonly present, which only do serious damage under exceptional circumstances. As a rule, the treatment of these diseases does not pay. Some leaf and stem diseases and all root diseases are dangerous, and, if unchecked, may cause great loss. To send specimens to Tocklai takes time. Time is often of the utmost importance and treatment should be put in hand at once. At the same time, specimens should always be sent to Tocklai for identification and the treatment may be modified later in accordance with special recommendations based on the nature of the particular disease. Most of the points raised in this article have been frequently emphasised in our publications, but the writer has endeavoured to put them together as concisely as possible so that the planter may get on with the job without the delay necessitated by hunting for mislaid copies of earlier publications.

PARASITIC FUNGI IN RELATION TO THE TEA PLANT.

Some fungi live outside the plant and thus can be killed by fungicides at any time, but most of the fungi causing tea diseases live mostly within the plant. Fungicides cannot reach such fungi at all times. It is, however, possible to kill the spores when they are formed on the surface of the plants and to protect the plant from infection by the spores by coating it with fungicide. If the life history of the fungus is known, the times of spraying may be arranged so that the plant is protected while the spores are being produced and the spores may be killed at the same time. In the tea districts the rain soon washes off the fungicide, and moreover the new leaf is continually forming on a plucked bush. It is necessary therefore to repeat the spraying at intervals. For instance,

in the case of Blister blight the first spraying will kill the spores actually present when the application is made and protect the foliage for a few days from attack. It will not kill the fungus which is developing inside the leaves. As from our knowledge of the life history of the fungus we know that it takes 10—11 days after infection to produce its fruits. It is necessary to keep the bush protected for that period, as the fungus in leaves infected just before the spraying would take 10—11 days to develop. As the spray fluid is washed off or the new leaves appear within a week, the spray fluid should be applied again about a week later.

Where the fungus is common in jungle round the tea it is obviously impossible to protect the plants from infection adequately by spraying, and other methods have to be found.

The Plant Reacts to Stimuli Caused by Mechanical Injury or Plant Disease.

When a plant is injured in any way, it sets to work to repair the injury. When a fungus is the cause of the injury, the plant reacts to stimulus produced by the fungus. Different fungi cause different reactions. Some cause the diseased portions of the plant to grow more rapidly, thus causing cankers, etc. Others kill the diseased tissues very rapidly and feed on the dead substance. By studying the action of the fungi on the tissues it is sometimes possible to devise means of killing the fungus, even though it is inside the plant, *e.g.*, the fungus causing Thyridaria tarda is frequently destroyed by the plant itself when conditions are favourable.

The tea plant in a normal condition is able to resist the attacks of many of the fungi which cause its disease, but when the vigour of the plant is lowered those fungi cause disease and make matters worse.

Manurial Treatment.

If a soil is deficient in any necessary constituent, the plants growing thereon are less vigorous and, in consequence, more susceptible to certain diseases. It has been found that deficiency in potash often predisposes plants to disease infection. Manuring with potassium nitrate or a mixture containing potash and nitrogen

in a readily available form will often check attacks of Brown blight, Red rust and Thyridaria tarda. The application of such a manure is only useful when the soil is moist and the plant is actively growing.

How Fungi are Distributed.

Fungus spores are usually very small indeed, and, in consequence, can be carried long distances by wind. Some spores have special arrangements to facilitate this, *e.g.*, filaments of Grey blight. Other spores have a sticky coat, *e.g.*, Brown blight, so that they stick to insects, etc., and are thus carried about. Some fungi which rarely produce spores, *e.g.*, Thread blight, are distributed by the dispersal of dead leaves, etc., bearing portions of the fungus mycelium thereon. Diseased tea bushes like diseased animals should be isolated as far as practicable. Whenever a large area of one kind of plant is found there is danger of epidemic disease. Some of the diseases of tea are always present, yet under ordinary circumstances do little damage, but there is always the possibility of their becoming serious under special conditions. There is a still greater possibility of new diseases appearing in epidemic form, and whenever a new disease is noticed no effort should be spared to eradicate it before it becomes general. The enormous damage which an epidemic of disease may cause should never be lost sight of and a constant watch should be kept for anything new.

What to do When an Outbreak of Serious Disease is Discovered.

Always send specimens of any unrecognised disease to Tocklai at once, with full particulars of soil, jat of tea, age of tea, weather conditions during the development of the disease, extent of damage, and any other relevant details. The disease may be doing little damage, but under other conditions it may become serious. If the specimen is sent to Tocklai, the department is able to investigate the disease and to be in a position to suggest remedies, should the disease at any time become serious.

In the Case of Stem or Leaf Diseases.

1. Isolate the bushes concerned by preventing coolies, cattle, etc., from touching them. All the necessary cultivation, etc., should be carried out by special coolies, using specially-marked implements. At the conclusion of the operations for the day the coolies and implements should be sprayed with lime-sulphur solution on the spot so that the disease will not be carried about.

The lime-sulphur solution does not injure the skin or clothing, but should not be allowed to get into the eyes. The solution is also a cure for itch and various other skin diseases.

2. Pluck or prune off all the diseased portions and burn them on the spot. If they are too green to burn alone, a little kerosine will help matters.

3. Spray the bushes thoroughly with a fungicide, *e.g.*, lime sulphur.

Repeat the plucking, pruning and spraying at intervals, depending on the nature of the disease.

Where there are numerous outbreaks occurring at the same time, treat the small ones first, isolating the larger areas until time permits treatment to be carried out on them.

In the Case of Root Diseases.

1. The areas containing the dead or dying bushes should be isolated and all the implements used in cultivation, etc., of such areas should be kept separate. There is no need to disinfect the coolies.

2. The edges of the large areas and all small areas should be dealt with first by digging out the dead and diseased bushes, taking great care to remove all the dead wood from the soil.

3. All the dead wood should be burned on the spot if possible. If it is not feasible, it should be removed in old bags or baskets and burned elsewhere. Care should be taken to either burn the bags or baskets or disinfect them thoroughly with lime-sulphur solution.

4. Watch for new outbreaks and deal with them at once.

5. Dig out all dead wood and heavily lime the soil some months before replanting.

In planting out, be very careful to clear out all the dead stumps. This operation is costly, but very desirable. Jacks are very useful for removing smaller trees, and the large stumps may be used as centres of the burning of piles of wood collected round them.

Spray Fluids.

For use in the rains *lime-sulphur* solution is the most satisfactory.

This solution is best prepared according to the following formula:—

Quicklime	... ...	20 lbs.
Sulphur	... ...	22½ lbs.
Water	... ...	50 gallons.

The lime should be put into a drum holding 50 gallons and slaked by adding water gradually. When it is fully slaked, add about 30 gallons of water and bring to the boil. When it is boiling add the sulphur gradually, stirring vigorously during the whole time, and when all the sulphur has been added pour in boiling water to the 50 gallons' mark. Boil for an hour longer, keeping the volume at 50 gallons by adding boiling water. This gives the stock solution, which, when cool, may be diluted with 10 or 12 volumes of water and used immediately.

Great care must be used in its preparation, and if it be desired to keep the stock solution, it must be stored in full, air-tight vessels, or, if the vessel is not full, with a layer of oil on the surface.

Lime-sulphur solution should not be stored in copper vessels, or sprayed on to bushes from copper spraying machines. Great care must be taken to see that all spraying machines are thoroughly cleaned out after use.

The sediment need not be thrown away, but may be boiled up with about 10 gallons of fresh water. The resulting liquid should be tested, when cool, with a hydrometer and diluted according to the table given in the spraying pamphlet. The water used for diluting the stock solution may be mixed with fresh cattle manure and carefully strained. This makes the fluid stick on better and renders it visible on the leaves.

This solution is very useful for the treatment of itch and ringworm on coolies.

For use in the cold weather *Burgundy mixture* is recommended, because it sticks on to the bushes for a long time.

To make 50 gallons 1% Burgundy mixture

Dissolve 5 lbs. of crystallised copper sulphate by suspending it in a piece of sacking in two and half gallons of warm water (if required immediately). If cold water is used, the copper sulphate may be left to dissolve overnight. In the same way dissolve 2·3 lbs. of soda ash.

Add the soda ash solution gradually to the copper sulphate solution, stirring all the time, until the mixture becomes neutral. This can be tested with litmus paper. The solution should be either neutral or very slightly alkaline, but never acid. The mixture will not be affected to any great extent by standing for a short time in iron vessels, but the copper sulphate solution will be. It is therefore necessary to dissolve this substance in wooden, copper or earthen vessels. The soda ash attacks iron a little but not sufficiently to make any serious change in the solution.

The addition of the above mixtures will make 5 gallons concentrated mixture which, when diluted to 50 gallons, will be 1% Burgundy mixture.

(Litmus paper is made up into little books of narrow strips. It is either blue or red. The red colour may be changed to blue by alkalis, and *vice versâ* by acids. Neutral solutions do not affect the colour of the paper.)

The Hydrometer.

The use of a hydrometer in testing the strength of solutions, such as copper sulphate, carbonate of soda or lime sulphur, is recommended. There are tables for this purpose in the spraying pamphlet. The solution must be cold when tested. By using the hydrometer it is possible to check the accuracy with which the solutions are being prepared.

A paint for use on pruning cuts may be prepared by dissolving 5 lbs. of copper sulphate in 10 gallons of water and making it up to the consistency of paint by adding slaked lime. The use of rice water instead of ordinary water is recommended, as it makes the paint stick better.

A suitable brush for painting cuts and applying caustic soda solutions is made as follows :—

Take a piece of bamboo, about 1½ inches in diameter and 2 feet long, having a knot at each end. Bore out the knots with an auger. Take a piece of tow of sufficient size, tie a piece of wire round the middle, leaving an end long enough to go the length of the bamboo and project at the one end. Thread the wire through the bamboo and pull the tow into position at the end. Fix the loose end by means of a wooden plug driven into the hole.

Spraying Machines.

The most useful ones are of the preasure type with internal pump. *Nozzles* should be the simplest obtainable—containing no springs or joints. A four-nozzle attachment has been found very useful for spraying large areas.

Don't use expensive spraying machinery for corrosive fluids, such as caustic soda. Use cheaply made brushes for such fluids.

Always have machines washed out thoroughly at the end of each day's work. When some solutions become concentrated by the evaporation of the water, they become able to attack the metal of the machines. The washing of the machines prevents this.

Dusting.

Dusting with sulphur mixed with fine silt or clay in the proportions of 1 of sulphur to 9 of the powder is recommended for protecting the bushes on the sides of roads and paths leading from infected areas. The dust should be extremely fine and should be distributed by a machine.

Always have spraying machines and materials ready for immediate use. This precaution may save a fortune some day.

Remember time means money, and neglect of a small outbreak may mean great loss.

METEOROLOGICAL OBSERVATIONS IN ASSAM, 1922

BY

C. R. HARLER, B.SC., A.I.C.

INTRODUCTION.

In 1920 the Agricultural Research Council in England appointed a Committee to consider the data supplied by the Meteorological Office and to make suggestions for the fuller use of such information. The Committee's report is full of interest to agriculturists and contains many suggestions which are being acted upon at Tocklai.

There are three ways in which a Meteorological Office assists agriculture, first by providing information as to prevailing or recently prevailing weather, secondly by issuing forecasts of the weather to be expected, and thirdly by research (7).

Obviously no weather forecasts can be made from Tocklai, for this necessitates a knowledge of meteorological conditions over a great area. So far our work has been one of recording and research.

There is an obvious connection between plant pathology and weather conditions. Thus Potato Blight is associated with wet, mildews with dry summers. With tea, we associate Brown Blight with hot, scorching sun, Red Spider with a bad growing period particularly drought, and Blister Blight with cold winds, under certain conditions, blowing from the hills. It is only by keeping a detailed account of the weather parallel with observations on pests and blights that the extent of the relationship between the two can be seen.

The influence of the atmospheric humidity on both tea growth and tea manufacture is of fundamental importance and is discussed in some detail later on.

The optimum temperature for tea growth has not yet been settled, neither has the most suitable rainfall. The former factor must vary considerably with other conditions and the latter is no doubt dependent largely on the type of soil and subsoil.

It is only by continuous and detailed observations that anything approaching a true correlation between the weather and the growth and condition of the tea plant can be made. When this has been done, the falling off in crop in any area will be more easy to explain than at present and at the same time the treatment of such an area will be simplified.

The observations made below are in continuation of those made in a previous Meteorological Report (4).

The Monsoon in Assam during 1922.

The monsoon in Assam differs considerably from that experienced generally in Northern India. In provinces other than Assam, the drought as a rule continues till about the middle of June and the rains ceases towards the end of September. The rain corresponds with the moving north of the thermal equator and the steady uptake of air from the Central Asiatic plateau enormously accentuates the inflow of rain bearing winds to North India.

In most parts of North India three definite seasons, cold, hot and wet, are distinguished, but in Assam there are roughly two, the cold, dry season and the wet, warm one.

In Bengal the year is divided by the Indians into six seasons. *Basanta* is the Spring season and corresponds roughly to February and March. *Grisma* is the hot or summer season and corresponds to April and May. These two seasons coincide with what is termed the hot weather. *Barsa* and *Sarat* are the rainy season, and the end of the rains corresponding to June, July and August, September. *Hemanta* is the beginning of winter, the dewy season, and

Seath is winter. These seasons fall in October, November and December, January respectively.

The Assamese have similar names which are adapted to the modified climate.

The climate of the Assam valley is dominated by the Tibetan plateau to the North and by the Patkoi range which forms the Southern boundary of the valley. Often, well on into May, cool breezes flow from the Himalayas into the valley. Before the break of the true Monsoon, rainfall is generally accompanied by a rise in temperature which denotes that the rain-bringing wind originated in the South. Rain clouds which once get into the valley usually circulate round the hills till they are dispersed, so that it often happens that the rain appears to come from the North.

During the period March, April, May, the weather is changeable and is usually alternately hot and cool with a general tendency to get hotter.

In June the uptake of air from the Tibetan plateau becomes steady and the Monsoon advances so that up the Assam valley a steady south-west wind blows and the sky is cloudy and overcast for two months. In August and September there is a period of comparative equilibrium and clear and cloudy skies alternate. Early in August it is frequently observed that the breeze blows direct from the North.

October sees the Monsoon definitely in retreat and the wind blows steadily from the North.

In the year under consideration only 73·89 inches of rain fell. This figure is 6·62 inches below the average but is quite sufficient to ensure a good tea crop if the distribution is good.

As was mentioned in a previous report (4) a first approximation to the degree of wetness may be obtained by dividing the product of the monthly rainfall and the number of wet days by the number of days in the month.

In the table is given the rainfall and the distribution at Tocklai for the past five years.

Table showing Monthly Rainfall and Degree of Wetness at Tocklai.

Months.	Rainfall in inches					Degree of wetness.				
	1918.	1919.	1920.	1921.	1922.	1918.	1919.	1920	1921.	1922.
January	0·12	0·28	0·63	1·63	0·74	0·004	0·02	0·04	0·42	1·58
February	1·26	0·97	2·73	0·86	0·12	0·18	0·17	0·87	0·21	0·01
March	6·37	0·75	6·15	4·21	3·14	3·29	0·07	2·97	1·22	0·81
April	5·91	7·41	9·08	14·03	7·79	2·16	1·91	3·60	10·29	3·11
May	15·42	6·57	6·73	9·28	6·16	6·96	2·54	2·38	5·08	3·17
June	14·92	22·09	9·89	7·71	11·67	8·61	12·51	6·59	6·42	10·11
July	18·20	16·37	14·18	14·52	12·87	11·77	10·56	8·46	9·84	10·87
August	19·48	10·71	9·22	9·71	19·23	11·31	4·42	5·94	6·57	16·12
September	12·44	9·59	6·17	14·23	7·32	6·22	5·75	3·08	9·49	3·90
October	2·42	9·40	2·47	5·15	2·65	0·31	3·33	0·72	2·66	0·59
November	0·40	0·10	0·40	nil	1·17	0·13	0·56	0·26		0·16
December	nil	0·01	0·13	1·14	1·03	...	0·01	0·01	0·11	0·16
Total	96·94	75·08	67·55	28·47	73·89	...	..	..	...	...

In order that the degree of wetness values for each month shall be directly comparable they must be combined with other factors, not the least important of which is temperature. For, a degree of wetness of 3 in October, when evaporation is decreasing owing to falling temperatures, will mean much more than a similar figure in September.

It is interesting to note that August 1919 was a bad period for tea growth, although the rainfall compared favourably with 1920 and 1921. But most of the 10·71 inches which fell in this month was precipitated in five days. This is shown in the degree of wetness which is considerably below that of the same month in 1920 and 1921.

The beginnings of 1918 and 1920 were the best early seasons for some years past and 1919 is remembered as being a stand out season with regard to the end, although the early part of the season was bad. It will be noticed that all three instances occur at periods of rainfall above the average.

On the chart the weekly rainfall is shown by means of black vertical lines.

So far as rainfall is concerned, there are two critical periods in the season. The first is in March, April and May, and the other in September and October. The rain seldom fails in the months between, but is usually in great excess.

In 1922 the start of the season was particularly bad, for the drought continued, with only one break, till the end of April. On this account transplanting was held up and infillings often failed. Unpruned tea suffered much on account of the amount of leaf it was carrying. Pruned tea did not produce much leaf till the rain came, and it then went steadily ahead of the unpruned.

The end of the season was also one of drought. September was a dry month and, but for two falls early in the month, there was no precipitation in October. Previous to this, much of the leeway following on the early rain shortage had been made up by means of excessively heavy falls doing more harm than good. With good late rains a crop well up to the average might have been expected.

The cause of this shortage of rain at the end of the season was apparently due to a barometric depression in the United Provinces and the Punjab. This deflected the general air movement from Assam, and when the depression had disappeared the wind swung round to the North and the chance of late rain diminished.

This is a case when meteorological observations over an extended area might have enabled an early prediction of the close of the tea season, with much advantage to the tea industry.

The rain which usually falls about Chrismas time is probably the result of the barometric depression which passes from Europe across Persia and into India.

Temperature and Humidity.

Observations in connection with many plants show that the dominating factor in plant growth is temperature. Below 42°F plant growth ceases and at present we use accumulated temperature above 42° as an index of favourable condition for plant growth. As the temperature increases so the rate of growth increases, till the thermic optimum is reached and then growth decreases. At the same time, this optimum varies with the duration of exposure of the plant. The longer the duration of the exposure, the lower is the optimum. Between the optimum and the vital temperature, *i. e.*, 42°, the rate of growth is doubled for every 18°F rise in temperature (6).

Now these factors are of the utmost importance in the study of the growth of tea. We do not yet know the exact optimum temperature for tea growth, but it is believed to be about 90°. As shown above, this optimum will be lower when the time of exposure is longer and higher when the time of exposure shortens. Now August is often a month of depression so far as tea crop is concerned, although, on the average, the maximum temperature is slightly less than that of June and July. This depression may be partly due to soil condition, but it may also be due to longer exposure in August and September, which results from skies less cloudy than in previous months with an advancing monsoon.

The year 1922 was remarkable for the steady temperatures during the monsoon period and shows a marked contrast to the previous season.

On the chart the average weekly maximum and minimum temperature are denoted by red lines. In the rains the difference between the two temperatures is about 10°F., whereas at other times it increases to 20°. This has an important influence on the vapour tension of the atmosphere.

Closely correlated with temperature and with rainfall is the humidity of the atmosphere. That humidity has a tremendous influence on the tea crop is undoubted, but only after many more observations can we say which type of observations—relative or absolute humidity, dew point or readings of the wet bulb thermometer—will be of most use to the tea industry. In any case, wet and dry bulb thermometer readings, from which humidity and dew point are calculated, should be made daily.

Here a brief account of the theory of the wet and dry bulb thermometer may be given. A more detailed account, together with general instructions to Meteorological Observers in India, is given in an Indian Government publication (3).

A common method of cooling water and air in India is by means of evaporation. Thus wet cloths hung round a fermenting room cool the air which passes through, becauses the moisture in the cloth evaporates and, in doing so, takes heat from the air. The quicker

the cloth dries the cooler becomes the air passing through it. Similarly earthenware vessels containing water keep cool by virtue of the thin film of water which soaks through to the outside of the vessel and evaporates.

The same thing happens with a wet bulb thermometer, which is simply an ordinary thermometer surrounded by a piece of muslin attached to a wick saturated with water. The wet bulb will be cooled because the muslin dries. The quicker this drying takes place the more the thermometer will be cooled and the greater will be the difference between the wet and the ordinary (dry bulb) thermometers.

During the misty mornings which occur in the cold weather there will be no difference between the wet and dry bulb thermometers, for no evaporation is possible. On a hot, dry day such as often occurs in May the difference will be great. Here, then, is a measure of the humidity of the atmosphere, for the greater the difference between the two thermometers, the dryer the atmosphere.

It is further necessary to distinguish between *relative* and *absolute* humidity. In the cold weather when a mist is lying about, the atmosphere is saturated and the relative humidity is 100. If the temperature were suddenly raised about 10°F., the mist would clear and the relative humidity would fall, as it often does, to about 70, although there is still the same amount of moisture in the atmosphere as there was when the air was cooler, *i.e.*, the absolute humidity is unchanged.

During the nights in the rains the atmosphere is generally saturated and the relative humidity is then 100, but the actual amount of moisture in the air is often three times the amount present in the cold weather when the atmosphere is saturated. This difference is not measured by the relative humidity, which is merely the amount of moisture in the air compared with that necessary to saturate the air at the same temperature. This latter quantity varies with temperature so that the same amount of moisture may correspond to any number of relative humidities.

The relative humidity varies greatly throughout the day and may alter from 100 at 10 A.M. to 50 at noon when the mist

clears. This is especially the case in the cold weather. The absolute humidity seldom shows such sudden variation, although it shows a steady change over periods of days.

The average weekly absolute humidity or vapour tension taken at Tocklai at 10 A.M. daily is shown by a blue line on the chart and is registered as inches of mercury. Thus, when the vapour tension is 1·10 it signifies that out of a barometric pressure equivalent to the weight of about 30 inches of mercury, 1·10 inches are due to water vapour.

Both the relative humidity and vapour tension (absolute humidity) are calculated very simply from wet and dry bulb readings by the aid of tables found in many meteorological books (1).

It will be understood that before the absolute humidity of the air can be appreciably increased there must be a hot period extending over several days and, at the same time, the nights must not be cold enough to precipitate as dew all the extra moisture taken up. It usually happens that right to the end of May, although the daily temperature rises to 90°, the absolute humidity does not greatly increase because the night temperatures fall to about 70°. In the monsoon no such fall occurs at night.

The question of humidity (humidity of air irrespective of rainfall) has an important bearing on the growth and manufacture of our tea as well as on insect and fungus attack.

So far as the growth of tea is concerned it appears that the crop follows more or less the vapour tension curve.

Brief mention was made of the mechanism of transpiration and its relation to atmospheric humidity in last year's report. When the air is moist the transpiration of the leaf is hampered and the bush must grow more leaf in order to be able to get rid of its excess moisture. It usually happens that excessive humidity goes with high temperatures, so that here the bush is reacting to two factors which are inter-related.

In 1921 the form of the crop and vapour tension curves showed a remarkable resemblance, and one was tempted to conclude

that there was a high degree of correlation between the two. In 1922, however, it is seen that there is not a close resemblance. If naturally there is a close correlation, then it must be concluded that the treatment of bushes in 1922 (*e.g.*, method of plucking) has not been such as to allow this relationship to be in evidence.

When the leaf is plucked and withering begins, the vital forces in the leaf diminish and the drying takes place more and more on physical lines. Wilting gives place to withering. In this case the influence of the absolute humidity decreases and that of relative humidity increases. In the damp nights experienced during the rains a good wither is impossible under ordinary conditions. It may be said that rapid growing weather is bad manufacturing weather.

This statement may be illustrated as follows :—

Opposite on charts I to IV are shown four graphs taken from the hygrograph. The hygrograph is an instrument which mechanically measures the wet and dry bulb readings throughout the day. The upper line represents the dry bulb reading, or the ordinary air temperature, and the lower line, the wet bulb reading. When the two lines come together it signifies that no evaporation is going on from the wet bulb, *i.e.*, the air is saturated. The further apart the two lines are, the dryer is the air and the less the relative humidity.

The first chart is for the week ending May 8th, 1921. This is a dry week with a steadily rising temperature and typical of what may be expected at this period. The nights are warm—the temperature scarcely falling below 80°—and the vapour pressure is rapidly mounting. The bushes are flushing well, but it is too dry for a good wither unless the side curtains of the withering house are lowered to reduce wind effect.

The second chart represents conditions two months later when the Monsoon is fully advancing. There is copious rainfall and the irregularities in the dry bulb reading during the day represent showers and cloudy intervals. In such dull, steamy weather, crop is plentiful but a good wither impossible.

The third chart is for the week ending July 31st, a fortnight later than the previous chart. The atmosphere is still saturated at night, but the night temperature is generally higher than during the week ending July 10th and the atmosphere by day is comparatively dry. A fair wither would be obtained. Good growth should also be obtained at this period, but as a matter of fact a spell of *banjhi*-ness had come over the bushes. This may have been the result of excessive leaf production earlier on.

The fourth chart is for the week ending October 14th. The form of this chart is similar to that of the week ending May 8th, but the temperature is about 10°F. lower. The bush at this period is not growing fast owing to the low temperature. A good wither is obtainable.

When the exact and separate significance of temperature and humidity in connection with the withering of leaf has been determined, great advances can be made in tea manufacture.

The length of the fermentation time must vary with the weather which, in turn, varies every day and throughout the day. Usually in September the time necessary for fermentation must be increased. It is common for the time to be increased from $3\frac{1}{2}$ hours in the rains to 5 hours in October.

Now the necessary increase in the time of fermentation is on the whole a steady one, but there are days when the time must be put back and days when it must be put forward a greater amount than usual. The planter of experience knows by the feel and the colour of the leaf when it should be ready for firing. With such a man tea making is an art, and it can only become a science when, by careful and detailed climatic observations, we can state definitely how long the fermentation process should be under any special set of conditions.

Sunshine.

At Tocklai the hours of bright sunshine are measured daily. The apparatus is a simple one and consist essentially of a closed cylinder in which is an aperture. Inside the cylinder is sensitized paper. As the sun traverses its path the spot of light

projected from the fixed aperture moves accross the piece of photographic paper divided according to hours, leaving a dark line.

The average daily sunshine is considerably less during the monsoon than at other times. The weekly average shows considerable variation and is roughly an inverse measure of the rainfall. Sunshine is the complement to rainfall. Long sunny days denote high temperatures and good growth, which is different from the forcing growth shown in dull weather when the shoot contains large sappy leaves and a big percentage of stalk.

It has been shown (5) that shade reduces the tannin content of the leaf, although the loss of quality in this direction is more or less counterbalanced by increased crop.

During the season 1921, teas on the whole were poor in liquors and pungency, in spite of the finer plucking resorted to in that year. A possible explanation of this is that the sunshine in this year was below the general average.

Another factor which would make for poor teas in 1921 was long, as opposed to close, plucking.

The table below shows the monthly sunshine average in hours over the past five years, recorded at Tocklai.

TABLE.

Year.	Jan.	Feb.	Mar.	Apl.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1918	6·95	6·14	4 23	5·76	5·10	3·31	3·71	3·74	5·00	6·22	6·27	6·51
1919	5·27	6·10	6·91	6·06	5 69	5·05	3·57	5·26	3·35	5·06	5·24	4·96
1920	4·60	3·96	4·39	4·61	4 32	3·89	5·22	5·08	5·62	4·90	6·07	5·03
1921	5·03	5·45	5·22	3·89	3·91	3·11	3·71	3·93	3·49	2 58	5·51	4·48
1922	5 30	7·42	4·50	6·07	6·03	4·11	4·52	3·50	4·55	6·10	5·91	6· 3

We may correlate fairly closely some of the pests and blights of tea with sunshine. Thus Brown Blight usually follows a hot, scorching sun. Red Spider on a waterlogged soil is dispelled by a sunny period, although the connection is not so close as might be expected. Any change in the weather which causes fresh growth overcomes Red Spider. Blister Blight disappears with the advent of a spell of sunshine, chiefly because the temperature rises.

The Soil Condition.

Throughout the year daily soil samples were taken from the top 9″ of the Tocklai Clearance. The soil here is a sandy silt with an optimum water content of about 14%. The average weekly moisture throughout the year is shown on the top line of the chart and the arrows denote cultivation. The moisture ranges from 10 to 20%.

During the first three months of the year the soil steadily dried out and at the end of March it was powdering badly and in a condition impossible for cultivation. At the beginning of April the drought ended, but there was not sufficient precipitation to greatly influence the subsoil nor to raise the water table to within a distance which would enable the upper soil to draw on it for moisture. The result was that in the middle of April, drought was again in evidence and the soil moisture fell sharply to 10%. With the coming rain again the moisture increased and, to about the end of May, it was almost at the optimum. In June it rose to about 19% and remained at about that figure till the rains began to tail off. It will be observed that on one occasion only did the moisture go beyond 20%.

For about three months in the middle of the rains no cultivation was done, but the jungle was kept down by sickling. The question of rains cultivation has been discussed elsewhere (2), but a remark may be made here on the September hoe. Now cultivation is apt to be a wasteful process. By cultivation soil food, especially nitrates, is made available, but when a heavy shower falls this food is washed away. This has been observed at Borbhetta in connection with nitrate accumulation. The ideal time to cultivate is a day or two after rain with a week or so of dry weather ahead. In this case the soil will not be so wet that a great amount of tilth is destroyed. This is a case where it pays to be weatherwise.

At Tocklai the soil, being a light one, is not liable to serious loss of tilth from rains cultivation, but from the aggregates of clay particles which are broken down, particles may be washed through the soil and there will be a tendency to pan formation, with the deep hoe, however, these particles should be brought to the surface again.

The soil temperature at 1 foot and 3 feet depths was taken twice daily, at 10 A.M. and 4 P.M. from May till the end of the year, at Tocklai. The soil in which the temperatures was taken is sandy, well drained and under grass.

Not enough figures are yet at hand to draw any conclusions nor to interpret any results. To the end of August the difference between temperature at 10 *a.m.* and 4 *p.m.* is about 3° F. on a clear day. In May or June the maximum temperature is reached at about 5 P.M. From September onwards the temperature at 1 foot follows the maximum air temperature.

At 3 feet the diurnal variation in temperature is practically nil. From May to July in the year under consideration it rose steadily from 80° to 89°, at which approximate temperature it stayed till September when it feel steadily to 75° in December. From September onwards the soil was warmer by 2° or 3° at 3 feet than at 1 foot.

During the hot weather it was observed that any great change in the temperature of the top foot is followed by a similar but smaller change at 3 feet about 30 hours later.

THE TEA CROP IN 1922.

For purposes of correlation of crop with meteorological observations the leaf from the Tocklai Clearance was taken. This is an area of 3½ acres consisting of half acre blocks of Burma, Kalline, China, Kharikatia, Singlo, Betjan and Panighat tea. During the year under consideration half of each block has been skiffed and the other half cut to 16″, *i.e.* 2″ new wood on the last year's pruning.

The total crop curve is shown by a black line on the chart. The form of the curve is quite different from that of last year (4) when five distinct flushes were noticeable. In 1921 the pruning was different, the tea which was skiffed in 1922 was cut to 10″ and the tea cut to 16″, in 1921 was cut to 14″.

The plucking at Tocklai is seven days and to the *jhanam* from the beginning of the season. This is very hard, and since

the plucking area was kept absolutely level there was a tendency to remove immature leaf. On this account the flushes were obliterated and a fairly level crop obtained throughout the year.

The most striking point in the crop curve is the depression in June, which appears to be the aftermath of the drought. The leaf at this period was all very small.

The season closed more rapidly than usual, and after the middle of September the crop fell off as suddenly as it had come on in the early part of the season.

The two red lines under the crop curve on the chart refer to the unpruned and medium pruned yields which go to make up the total crop denoted by the black curve. The continuous line represents the unpruned and the broken line the medium pruned tea. Few remarks are necessary. It is easily seen that 1922 was a season which, by reason of the early drought, was all against unpruned tea, carrying as it does a lot of leaf. By the time the medium pruned tea was carrying its full complement of leaf, the drought had broken.

It will be noticed that at the end of the crop curve a break is denoted. On account of the falling off in the crop, a ten-day pluck had to be made.

In conclusion, mention may be made of the value of keen and detailed observation in all agricultural practices. To be successful in agriculture the power of observation must be highly developed. But isolated observations are of little use and it is only when two phenomena are correlated that scientific advancement can be made.

Every stage in tea growth and manufacture is profoundly influenced by the weather. A set of meteorological observations, as full as is practicable, should be taken on every garden. Rainfall, maximum and minimum temperatures, humidity are all easily measured. Soil temperature and sunshine records would follow. It is only in this manner that knowledge concerning weather and crop which is now vague and unconscious can be co-ordinated and correlated.

References.

(1) Blanford—Tables for the Reduction of Meteorological Observations.

(2) Carpenter and Cooper—Cultivation during the Rains. Ind. Tea Assoc., Sci. Dept., Quarterly Jour., part I, 1922.

(3) Eliot—Instructions to Observers of the Indian Meteorological Department.

(4) Harler--Meteorological Observations in Assam. Ind. Tea Assoc., Quarterly Jour., part I, p. 11, 1922.

(5) Hope—Experiments on the Quality of Tea. Published by Ind. Tea Assoc.

(6) Lehenbaure—Int. Rev. Sci. Prac. Agr. Year XII, No. 8, p. 934, August 1921.

(7) Meteorology and Agriculture—Jour. Min. Agr., Vol. XXIX, No. 5, p. 432, August 1922.

NOTES.

A Note on the use of Perman's Expressor.—During the rains when the atmosphere is very humid it is often impossible to wither tea leaf sufficiently before it goes sour. In many cases expressors are employed, and although by this means the degree of the wither is not altered, rolling is facilitated.

What shall be done with the expressed juice and how much valuable matter does it contain are important questions. The first question was discussed in part II of the Scientific Department Quarterly Journal for 1922 and it was stated that the juice may be used by putting on leaf which is just going to be fired. The juice, after expression, should not be kept till the leaf from which it is obtained is ready for firing.

Samples of expressor juice from a Darrang Tea garden were analysed for total solids and tannin content. The leaf expressed had been withered to different degrees. The analyses were as follows:—

Sample:—Kutcha leaf (19 hours)—

Tannin	...	0·257 lbs. per gallon.
Total solids	...	0·96 lbs. „

Sample:—10-anna wither (20 hours)—

Tannin	...	0·294 lbs. per gallon.
Total solids	...	1·25 lbs. „

Sample:—14-anna wither (19 hours)—

Tannin	...	0·350 lbs. per gallon.
Total solids	...	1·41 lbs. „

Thus the richness of the expressed liquor increases with the completeness of the wither.

The actual loss made on the output of finished tea by using the expressor and discarding the juice may easily be calculated.

Thus, considering the highest value, 1·41 lbs. total solids, and assuming that a maund of leaf yields $\frac{3}{4}$ gallon juice and makes 32 lbs. finished tea (this assumes the leaf before rolling to contain 60% moisture), then the loss per 32 lbs. tea will be 1·05 lbs. or just over 3%. This value corresponds with observations made in factories in other parts of Assam.

With kutcha leaf taking the moisture content of the leaf before rolling at 75%, the loss per maund finished tea would be 3·6%.

C. R. H.

C. O. P.—1,500—22-2-1923.

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